The Use of Quality and Quantity of Publication as Criteria for Evaluating Scientists

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PREFACE

This publication deals with the quality and quantity of scientific research publications of some 3,000 scientists in the Agricultural Research Service. It is based on responses to a questionnaire sent to all scientists in ARS who were in grades GS–7 and above.

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Miss Edith LeRoy in the Administrative Services Division was principally responsible for the design of the questionnaire.

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Finally, special acknowledgment must go to the 3,207 scientists in ARS who responded to the questionnaire. It took much conscientious effort on their part to complete this rather complex questionnaire.

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The Use of Quality and Quantity of Publication as Criteria for Evaluating Scientists

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SUMMARY

The complete publication records to January 1, 1965, of some 3,000 scientists in the Agricultural Research Service (ARS) were considered. The scientists ranged in age from 19 to 69 and in GS grades from 7 to 18. Forty-four and three-tenths percent of the scientists had doctor's degrees; 28 percent had master's or professional medical degrees; 26.2 percent had bachelor's degrees; and 1.5 percent had no degree.

The total number of publications per scientist ranged from 0 to 278. Thirteen hundred scientists had 10 or less publications; 1,426 had between 11 and 50 publications; 255 had between 51 and 100 publications; 44 had over 100 publications; and 4 had over 200 publications.

When the scientists were separated by age, there was still a wide variation in the number of publications per scientist. Even at age 67, the spread was from 4 to 239 publications. When quality of publications is considered along with quantity of publications to get a publication score, there is still a widespread difference between scientists of the same age. (Total publication score = the summation of the products of publication credit (from 0.1 to 1.0—depending upon the number of authors) and rank order (quality measure from 1 to 100) for individual papers.) Over half of the scientists (1,594) had total publication scores of less than 300; 1,266 of these had scores under 200 and 806 had scores under 100; yet 9 scientists had scores over 3,000.

The mean number of publications and mean publication score were calculated for scientists of the same age from age 22 to age 69. The mean number of publications ranged from 0 at age 22, 5.2 at age 30, 14.4 at age 40, 27.2 at age 50, 39.8 at age 60, to 65.2 at age 69. The mean publication score ranged from 0 at age 22, 71.9 at age 30, 250 at age 40, 569 at age 50, 851 at age 60, to 1,108 at age 69.

Publication score per year is a better measure than total publication score for use in comparing scientists, since publication score per year eliminates the variables of age and length of experience. The mean publication score per year ranged from 1.8 for scientists in grade 7, 13.6 for scientists in grade 11, 31.6 for scientists in grade 13, to 45.7 for scientists in grade 15.

Scientists with doctor's degrees had a mean number of publications per year of 1.68 and a mean publication score per year of 31.4. Scientists with master's or professional medical degrees had a mean number of publications per year of 1.24 and a mean publication score per year of

20.4. Scientists with bachelor's degrees had a mean number of publications per year of 0.89 and a mean publication score per year of 13.8.

Scientists who have been publishing for 21 or more years had a mean number of publications per year of 1.68 and a mean publication score per year of 31.2. Scientists who have been publishing from 11 to 20 years had a mean number of publications per year of 1.51 and a mean publication score per year of 26.8. Scientists who have been publishing from 0 to 10 years had a mean number of publications per year of 1.09 and a mean publication score per year of 17.6. Contrary to generally held views, there was a steady increase in publication output with age.

Publications per year and publication score per year were highly correlated with promotions for those scientists who have been employed continuously by ARS since January 1, 1955.

The net change in quality of ARS scientists in two periods was calculated. It was found that there was a small net decrease in quality from June 30, 1956, to June 30, 1960, and a small net increase in quality from June 30, 1960, to June 30, 1965. These differences in the two periods are believed to be related to the change to the "man in the job" concept of classifying scientists which was adopted in 1959.

ARS does a good job of selecting research supervisors from scientists considerably above average in ability.

ARS pays its scientists in accordance with their productivity. Those scientists in the top 10 percentile of salary for their age produced six times as many publications and had publication scores eight times those of scientists in the bottom 10 percentile of salary for their age. The means for each 10 percentile in salary for their age lie in a straight line on a logarithmic scale.

The publications of 89 scientists selected at random were evaluated by 10 peer groups representing 10 research divisions. The members of each peer group independently evaluated the publications of up to 11 scientists in its own division. The publications of each scientist were evaluated independently by from four to seven peers. In peer groups representing divisions having a narrow range of scientific disciplines, the independent peer evaluations were fairly consistent with each other. In peer groups representing divisions with a wide range of disciplines, the independent peer evaluations varied widely. However, in 6 peer groups, where 5 peers in each group independently evaluated the publications of 10 scientists, the rank orders (based on publication score per year) assigned the 10 scientists by each of the 5 peers were remarkably consistent. Three of the six groups had a wide range of disciplines and three had a narrow range.

Finally, based on the foregoing analysis and with much advice from a large number of scientists, a plan for evaluating scientific research publications is presented. The plan deals with who should make the evaluations, the division of credit among authors, and the assessment of quality of publications.

Introduction

The Agricultural Research Service (ARS) classifies and promotes its scientists in accordance with the Civil Service Commission Research Grade-Evaluation Guide (*9*).[1] An article by Dr. P. A. Wells in *Research Management* (*10*) describes this guide and discusses the background of its development. The classification and promotion program for research scientists is carried out through the mechanism of Division Personnel Evaluation Committees. These committees are composed of senior research scientists with backgrounds similar to the scientists being evaluated and a personnel classification officer. Dr. Wells expressed the views of ARS when he stated: "We find that the system is simple. It is readily understood. It ranks positions in proper relationship, and it is equitable across disciplinary lines. Our senior scientists, who have devoted time and effort to make it work, feel that the system is very effective and even though a substantial amount of time in study and committee deliberation is required, they feel the end result justifies the price. . . . The system is not perfect, but it is the most important advance in classification since the original Classification Act was passed in 1923."

In an effort to make a good system even better, a study was undertaken to "Develop more reliable criteria, methods, and techniques for evaluating qualifications, achievements, and professional stature of scientists in ARS." The first phase of the study, which is reported here, deals with the evaluation of the quality and quantity of a scientist's research publications. It considers the relation of the scientist's publication output to his training, age, length of experience, position title, grade, previous employment, work location, and Merit Index.[2] It examines the correlation between publication output and promotions. It compares peer evaluations of research publications with a scientist's own evaluation. It also evaluates the net change in quality of ARS scientists in two time periods. Finally, the results of the study are used to develop a plan for evaluating the quality and quantity of a scientist's research publications.

The data used in the study came from 3,207 responses to a questionnaire sent to all research scientists in ARS in grades GS–7 and above. This represented responses from more than 95 percent of all research scientists in these grades. The questionnaire and instructions for its use are presented in the appendix. Briefly, the questionnaire required the respondent to evaluate the quality and quantity of his own publications on the basis of guides presented in the instructions. The first guide concerned the proportion of credit each author on multiple-author papers should receive (see appendix, sec. B). Total credit added to 1.0 for a single paper. The second guide related to the quality of publications based on the impact the publications had or could be expected to have on science, agriculture, or public welfare. (See appendix, sec. A and the list of publications on pp. 60 to 74.) The guide consisted of a set of publications, which the research division directors in ARS had given rank orders from 100 to 1, that the scientist could compare with his own publications in establishing their rank order.

Using these guides, the respondent, for each of his papers, determined an author credit value (from 0.1 to 1.0) and a rank order (from 100 to 1). He then multiplied the credit by the rank order to get a publication score for that paper ($0.5 \times 30 = 15$). Next, he added the values on all papers for given time periods to get (1) total publications, (2) total publication credit, and (3) total publication score. He then divided these totals by the years in the time period to get per-year values.

It was expected that some scientists would overrate their publications and some would underrate theirs, but it was believed that means determined from fairly large numbers of scientists would have a reasonable relation to peer ratings. Several scientists sent in their work sheets showing the rank order assigned to each of their papers. It appeared that they had done a reasonable job of ranking.

[1] Italic numbers in parentheses refer to Literature Cited, p. 50.

[2] Dr. Shockley (7), 1956 Nobel Prize winner in physics, defines Merit Index for an individual for a given date as the fraction of the employees of his age that the individual exceeds in salary. Thus, the person having the top salary for his age will have an index of 1.0; the person having the median salary will have an index of 0.5; and the person having the lowest salary will have an index of 0.

Characteristics of the Population Completing the Questionnaire

Of the 3,207 scientists who responded to the questionnaire, 15 were in grades 16 and above. Because of the low numbers in grades 16, 17, and 18, the analyses in this paper are confined to grades 7 through 15. The distribution of scientists by grade and by degree is shown in table 1.

Leisner's (*4*) figures for all biologists and agricultural scientists responding to the 1962 canvass by the National Register of Scientific and Technical Personnel show 38.8 percent with doctor's degrees, 34.0 percent with master's and professional medical degrees, and 25.6 percent with bachelor's degrees. The National Science Foundation reports that 35 percent of all scientists on the register in 1964 had doctor's degrees, 30 percent had master's and professional medical degrees, and 32 percent had bachelor's degrees (*5*).

The ages of ARS scientists ranged from 19 to 69. The age distribution by grade and by degree is shown in table 2 and in figures 1 and 2. The distribution of scientists by grade and by degree by age groups is shown in table 3.

TABLE 1.—*Number and percentage distribution of ARS scientists by grade and by degree*

Degree	Grade							Total	Percentage distribution
	7	9	11	12	13	14	15		
No degree	15	12	12	7	3	0	0	49	1. 5
B.S., B.A.	131	198	219	140	91	40	20	839	26. 3
M.S., M.A., D.V.M	32	135	264	226	137	69	31	894	28. 0
Ph. D., Sc. D	1	6	155	511	405	197	135	1, 410	44. 2
Total	179	351	650	884	636	306	186	3, 192	100. 0
Percentage	5. 6	11. 0	20. 4	27. 7	19. 9	9. 6	5. 8	100. 0	

TABLE 2.—*Age distribution of ARS scientists by grade and by degree*

Age	Grade							Degree				Total
	7	9	11	12	13	14	15	Ph. D.	M.S.	B.S.	None	
Over 65	3	2	7	17	16	12	11	29	21	16	2	68
65	1	2	4	3	7	5	3	11	8	6	0	25
64	1	2	0	14	6	5	3	12	12	7	0	31
63	0	0	3	5	8	6	6	13	9	5	1	28
62	0	2	2	9	12	8	8	21	11	8	1	41
61	1	0	7	8	10	9	9	19	12	13	0	44
60	0	1	10	15	20	11	9	35	16	15	0	66
59	0	2	5	12	10	16	5	21	14	14	1	50
58	2	2	7	13	10	10	7	20	17	13	1	51
57	0	5	6	10	12	9	10	11	23	17	1	52
56	0	2	6	11	16	12	8	27	11	15	2	55
55	0	4	11	10	11	11	10	17	16	21	3	57
54	0	4	6	10	6	10	9	13	15	16	1	45
53	0	2	11	14	16	8	9	22	19	16	3	60
52	1	6	9	19	16	14	9	23	30	19	2	74
51	4	4	13	15	17	16	5	33	18	22	1	74
50	1	5	14	16	12	19	11	39	17	20	2	78
49	2	3	18	15	23	9	8	34	16	27	1	78
48	1	2	15	21	14	12	12	41	16	19	1	77
47	4	3	12	30	22	12	5	34	33	21	0	88
46	1	9	10	25	19	11	6	35	21	23	2	81

TABLE 2.—*Age distribution of ARS scientists by grade and by degree*—Continued

Age	Grade							Degree				Total
	7	9	11	12	13	14	15	Ph. D.	M.S.	B.S.	None	
45	3	9	24	36	35	11	2	53	31	34	2	120
44	5	13	21	36	38	16	9	60	48	29	1	138
43	0	7	11	42	40	10	3	60	33	19	1	113
42	3	9	21	27	26	7	5	49	24	24	1	98
41	1	4	35	40	34	11	0	63	34	27	1	125
40	2	6	30	32	22	6	2	45	28	24	3	100
39	4	11	25	32	26	4	1	48	31	22	2	103
38	2	11	29	26	24	7	0	51	22	25	1	99
37	4	8	36	52	25	5	0	79	31	19	1	130
36	0	10	22	46	25	1	1	68	21	15	0	105
35	3	20	28	41	18	2	0	63	31	18	0	112
34	7	25	32	33	18	1	0	58	27	29	2	116
33	9	21	32	33	9	0	0	48	26	30	0	104
32	6	8	29	31	5	0	0	41	19	19	0	79
31	10	23	29	22	6	0	0	33	25	31	1	90
30	10	15	18	25	1	0	0	32	20	16	1	69
29	10	23	23	13	1	0	0	23	19	26	2	70
28	15	27	17	14	0	0	0	19	27	27	0	73
27	9	20	9	6	0	0	0	4	22	18	0	44
26	15	11	3	4	0	0	0	3	11	20	0	33
25	17	5	0	1	0	0	0	0	8	15	0	23
Under 25	22	3	0	0	0	0	0	0	1	19	5	25

TABLE 3.—*Number of scientists by grade and degree, by age group*

Age and degree	Grade							Total
	7	9	11	12	13	14	15	
Under 28 years								
No degree	5	0	0	0	0	0	0	5
B.S., B.A	51	17	4	0	0	0	0	72
M.S., M.A., D.V.M	7	22	6	7	0	0	0	42
Ph. D., Sc. D	0	0	2	4	0	0	0	6
Total	63	39	12	11	0	0	0	125
28–32 years								
No degree	0	4	0	0	0	0	0	4
B.S., B.A	41	57	18	3	0	0	0	119
M.S,. M.A., D.V.M	10	34	54	11	1	0	0	110
Ph. D., Sc. D	0	1	44	91	12	0	0	148
Total	51	96	116	105	13	0	0	381
33–37 years								
No degree	3	0	0	0	0	0	0	3
B.S., B.A	15	48	37	10	1	0	0	111
M.S., M.A., D.V.M	5	36	58	27	10	0	0	136
Ph. D., Sc. D	0	0	55	168	84	9	1	317
Total	23	84	150	205	95	9	1	567

TABLE. 3.—*Number of scientists by grade and degree, by age group*—Continued

Age and degree	Grade							Total
	7	9	11	12	13	14	15	
38–42 years								
No degree	3	1	3	1	0	0	0	8
B.S., B.A	6	20	57	29	9	1	0	122
M.S., M.A., D.V.M	3	18	54	37	21	6	0	139
Ph. D., Sc. D	0	2	26	90	102	28	8	256
Total	12	41	140	157	132	35	8	525
43–47 years								
No degree	1	1	4	0	0	0	0	6
B.S., B.A	9	23	30	36	21	5	2	126
M.S., M.A., D.V.M	2	16	31	57	34	20	6	166
Ph. D., Sc. D	1	1	13	76	99	35	17	242
Total	13	41	78	169	154	60	25	540
48–52 years								
No degree	3	2	0	1	1	0	0	7
B.S., B.A	4	15	33	22	21	9	3	107
M.S., M.A., D.V.M	2	3	28	25	17	15	7	97
Ph. D., Sc. D	0	0	8	38	43	46	35	170
Total	9	20	69	86	82	70	45	381
53–57 years								
No degree	0	2	2	4	2	0	0	10
B.S., B.A	0	12	18	18	17	12	8	85
M.S., M.A., D.V.M	0	3	17	24	19	12	9	84
Ph. D., Sc. D	0	0	3	9	23	26	29	90
Total	0	17	40	55	61	50	46	269
58–62 years								
No degree	0	2	1	0	0	0	0	3
B.S., B.A	2	2	20	14	12	9	4	63
M.S., M.A., D.V.M	1	3	9	22	19	10	6	70
Ph. D., Sc. D	0	0	1	21	31	35	28	116
Total	3	7	31	57	62	54	38	252
Over 62 years								
No degree	0	0	2	1	0	0	0	3
B.S., B.A	3	4	2	8	10	4	3	34
M.S., M.A., D.V.M	2	0	7	16	16	6	3	50
Ph. D., Sc. D	0	2	3	14	11	18	17	65
Total	5	6	14	39	37	28	23	152

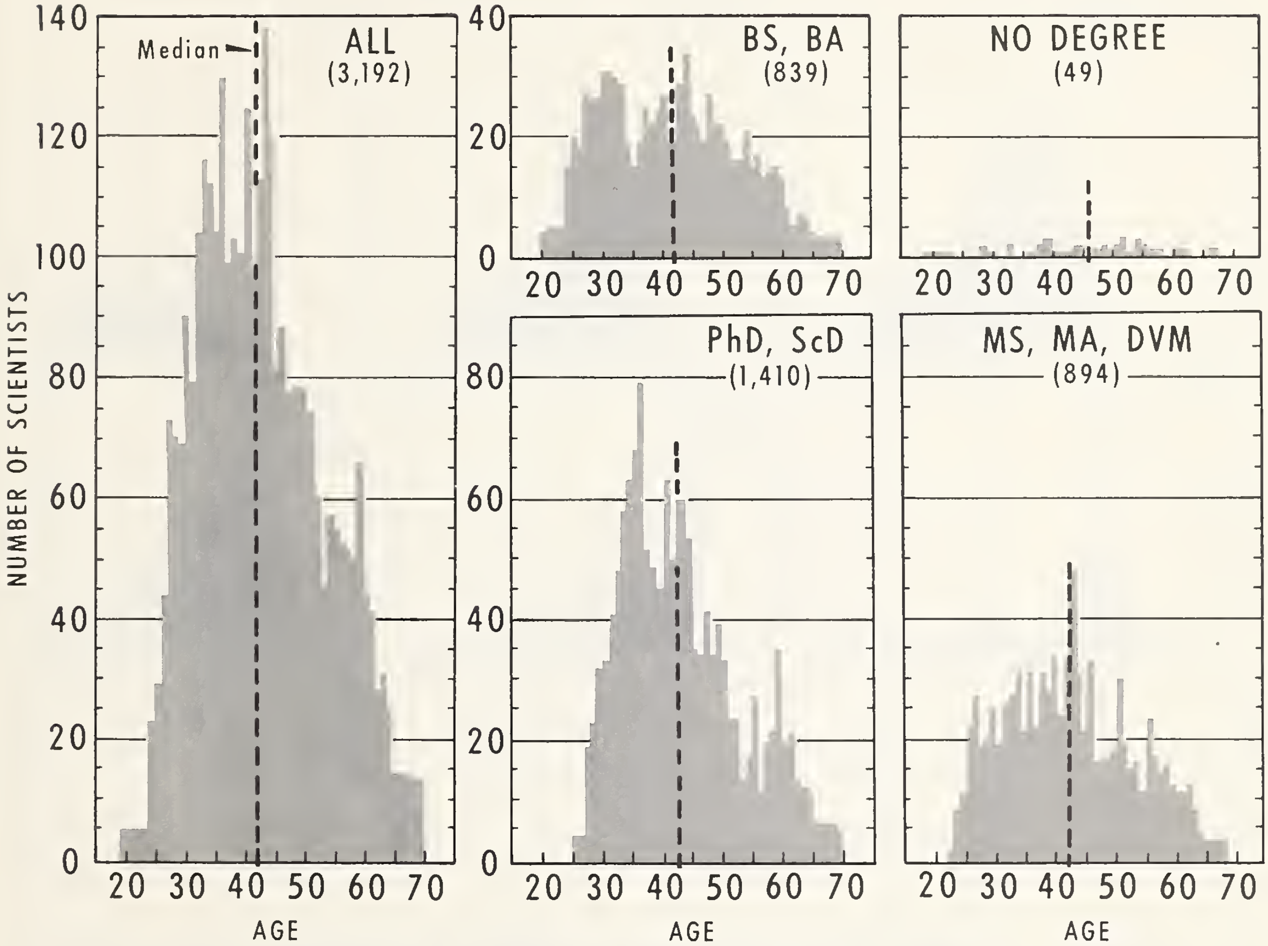

FIGURE 1.—Age distribution of ARS scientists—all and by degree.

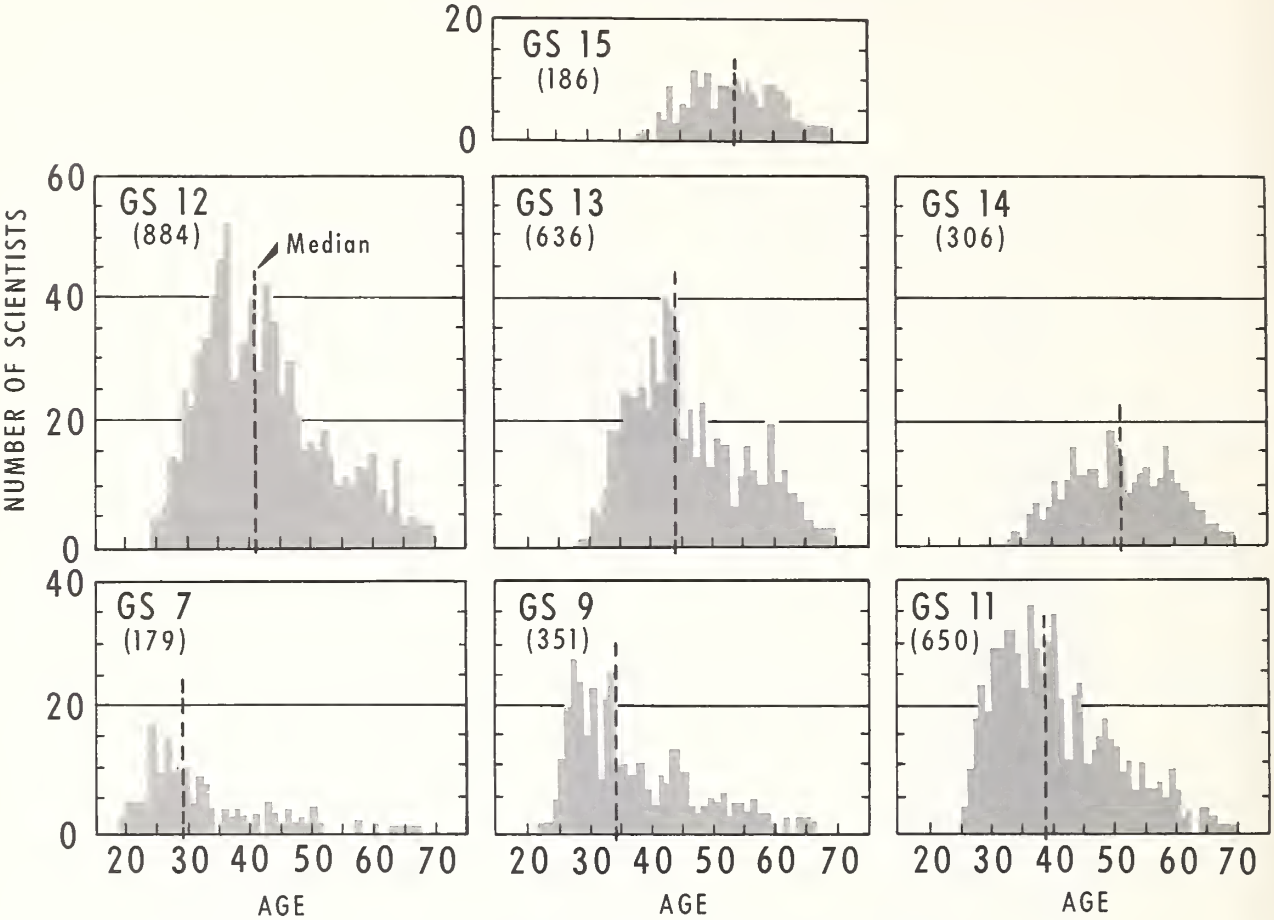

FIGURE 2.—Age distribution of ARS scientists by grade.

Individual Variation in the Number and Quality of Research Publications

Since in this and following sections of the report some responses could not be used, the number of respondents will differ from those given in the previous section. The principal reason for not using responses was that publication records asked for were for the period before January 1, 1965, and a number of scientists were hired between that time and August 16, 1965, when the questionnaire was sent out.

It is well known that in any group of scientists the number of publications per scientist will vary widely. ARS scientists follow the general trend. The total number of publications per scientist ranged from 0 to 278. Thirteen hundred scientists had 10 or less publications; 1,426 had between 11 and 50 publications; 255 had between 51 and 100 publications; and 44 had over 100 publications. A frequency distribution showing the number of scientists by grade having a given number of publications is given in table 4. The percentage distribution of scientists having a given number of publications is given by grade in table 5 and the cumulative percentage is shown in table 6 and figure 3.

TABLE 4.—*Number of scientists having a given number of publications, total and by grade*

Publications	Grade							Total	Cumulative total
	7	9	11	12	13	14	15		
0	71	56	32	18	1			178	
1	22	39	35	16	2	1		115	293
2	16	48	41	21	2			128	421
3	8	37	40	25	9		1	120	541
4	13	22	49	37	3			124	665
5	5	22	45	46	6			124	789
6	3	18	42	34	10			107	896
7	4	18	47	38	12	1	1	121	1, 017
8		14	29	41	11	1	1	97	1, 114
9	3	7	29	36	16	2	1	94	1, 208
10		4	22	40	23	1	2	92	1, 300
11 to 15	3	27	89	150	90	14	6	379	1, 679
16 to 20	2	8	49	99	92	22	6	278	1, 957
21 to 25		6	29	73	85	27	9	229	2, 186
26 to 30		1	18	54	58	32	10	173	2, 359
31 to 35		1	7	25	44	40	12	129	2, 488
36 to 40			6	22	37	22	11	98	2, 586
41 to 45		1	3	17	22	15	11	69	2, 656
46 to 50			3	8	22	24	14	71	2, 726
51 to 55			1	7	22	20	9	59	2, 785
56 to 60				4	10	15	9	38	2, 823
61 to 65			1	4	8	12	10	35	2, 858
66 to 70				5	9	12	11	37	2, 895
71 to 75					3	12	10	25	2, 920
76 to 80				1	1	9	2	13	2, 933
81 to 85					4	5	6	15	2, 948
86 to 90			1	1	3		6	11	2, 959
91 to 95					3	3	9	15	2, 974
96 to 100						1	6	7	2, 981
101 to 105					2	3	1	6	2, 987
106 to 110					3		3	6	2, 993
111 to 115						1	3	4	2, 997
116 to 120						1	2	3	3, 000
121 to 125					1	1	2	4	3, 004
126 to 130						1	1	2	3, 006
131 to 135							3	3	3, 009
136 to 140						1	1	2	3, 011
141 to 145						1		1	3, 012
146 to 150				1		1		2	3, 014
151 to 175						1	3	4	3, 018
176 to 200						1	2	3	3, 021
201 to 250				1	1		1	3	3, 024
251 to 300							1	1	3, 025
Total	150	329	618	824	615	303	186	3, 025	

TABLE 5.—*Percent of scientists having a given number of publications, total and by grade*

Publications	Grade							Total
	7	9	11	12	13	14	15	
0	47. 33	17. 02	5. 18	2. 18	0. 16			5. 88
1	14. 67	11. 85	5. 66	1. 94	. 33	0. 33		3. 80
2	10. 67	14. 59	6. 63	2. 55	. 33			4. 23
3	5. 33	11. 25	6. 47	3. 03	1. 46		0. 54	3. 97
4	8. 67	6. 69	7. 93	4. 49	. 49			4. 10
5	3. 33	6. 69	7. 28	5. 58	. 98			4. 10
6	2. 00	5. 47	6. 80	4. 13	1. 63			3. 54
7	2. 67	5. 47	7. 61	4. 61	1. 95	. 33	. 54	4. 00
8		4. 26	4. 69	4. 98	1. 79	. 33	. 54	3. 21
9	2. 00	2. 13	4. 69	4. 37	2. 60	. 66	. 54	3. 11
10		1. 22	3. 56	4. 85	3. 74	. 33	1. 08	3. 04
11 to 15	2. 00	8. 21	14. 40	18. 20	14. 63	4. 62	3. 23	12. 53
16 to 20	1. 33	2. 43	7. 93	12. 01	14. 96	7. 26	3. 23	9. 19
21 to 25		1. 82	4. 69	8. 86	13. 82	8. 91	4. 84	7. 57
26 to 30		. 30	2. 91	6. 55	9. 43	10. 56	5. 38	5. 72
31 to 35		. 30	1. 13	3. 03	7. 15	13. 20	6. 45	4. 26
36 to 40			. 97	2. 67	6. 02	7. 26	5. 91	3. 24
41 to 45		. 30	. 49	2. 06	3. 58	4. 95	5. 91	2. 28
46 to 50			. 49	. 97	3. 58	7. 92	7. 53	2. 35
51 to 55			. 16	. 85	3. 58	6. 60	4. 84	1. 95
56 to 60				. 49	1. 63	4. 95	4. 84	1. 26
61 to 65			. 16	. 49	1. 30	3. 96	5. 38	1. 16
66 to 70				. 61	1. 46	3. 96	5. 91	1. 22
71 to 75					. 49	3. 96	5. 38	. 83
76 to 80				. 12	. 16	2. 97	1. 08	. 43
81 to 85					. 65	1. 65	3. 23	. 50
86 to 90			. 16	. 12	. 49		3. 23	. 36
91 to 95					. 49	. 99	4. 84	. 50
96 to 100						. 33	3. 23	. 23
101 to 105					. 33	. 99	. 54	. 20
106 to 110					. 49		1. 61	. 20
111 to 115						. 33	1. 61	. 13
116 to 120						. 33	1. 08	. 10
121 to 125					. 16	. 33	1. 08	. 13
126 to 130						. 33	. 54	. 07
131 to 135							1. 61	. 10
136 to 140						. 33	. 54	. 07
141 to 145						. 33		. 03
146 to 150				. 12		. 33		. 07
151 to 175						. 33	1. 61	. 13
176 to 200						. 33	1. 08	. 10
201 to 250				. 12	. 16		. 54	. 10
251 to 300							. 54	. 03
Total	100. 00	100. 00	100. 00	100. 00	100. 00	100. 00	100. 00	100. 00

Table 6.—*Cumulative percentage of scientists having a given number or fewer publications, total and by grade*

Publications	Grade							Total
	7	9	11	12	13	14	15	
0	47.33	17.02	5.18	2.18	0.16			5.88
1	62.00	28.87	10.84	4.12	.49	0.33		9.68
2	72.67	43.46	17.47	6.67	.82			13.91
3	78.00	54.71	23.94	9.70	2.28		0.54	17.88
4	86.67	61.40	31.87	14.19	2.79			21.98
5	90.00	68.09	39.15	19.77	3.75			26.08
6	92.00	73.56	45.95	23.90	5.38			29.62
7	94.67	79.03	53.56	28.51	7.33	.66	1.08	33.62
8		83.29	58.25	33.49	9.12	.99	1.62	36.83
9	96.67	85.42	62.94	37.86	11.72	1.65	2.16	39.94
10		86.64	66.50	42.59	15.46	1.98	3.24	42.98
11 to 15	98.67	94.85	80.90	60.79	30.09	6.60	6.47	55.51
16 to 20	100.00	97.28	88.83	72.93	45.05	13.86	9.70	64.70
21 to 25		99.10	93.53	81.79	58.87	22.77	14.54	72.27
26 to 30		99.40	96.43	88.34	68.30	33.33	19.92	77.99
31 to 35		99.70	97.56	91.37	75.45	46.53	26.37	82.25
36 to 40			98.53	94.04	81.47	53.79	32.28	85.49
41 to 45		100.00	99.02	96.10	85.05	58.74	38.19	87.77
46 to 50			99.51	97.07	88.63	66.66	45.72	90.12
51 to 55			99.67	97.92	92.21	73.26	50.56	92.07
56 to 60				98.41	93.84	78.21	55.40	93.33
61 to 65			99.83	98.90	95.14	82.17	60.78	94.49
66 to 70				99.51	96.60	86.13	66.69	95.71
71 to 75					97.09	90.09	72.07	96.54
76 to 80				99.63	97.25	93.06	73.15	96.97
81 to 85					97.90	94.71	76.38	97.47
86 to 90			100.00	99.75	98.39		79.61	97.83
91 to 95					98.88	95.70	84.45	98.33
96 to 100						96.03	87.68	98.56
101 to 105					99.21	97.02	88.22	98.76
106 to 110					99.70		89.83	98.96
111 to 115						97.35	91.44	99.09
116 to 120						97.68	92.52	99.19
121 to 125					99.86	98.01	93.60	99.32
126 to 130						98.34	94.14	99.39
131 to 135							95.75	99.49
136 to 140						98.67	96.29	99.56
141 to 145						99.00		99.59
146 to 150				99.87		99.33		99.66
151 to 175						99.66	97.90	99.79
176 to 200						100.00	98.98	99.89
201 to 250				100.00	100.00		99.52	99.99
251 to 300							100.00	100.00

Table 6 and figure 3 bring out some interesting relationships. It would appear that the following relationships between the number of publications and the percentage of scientists in different grades approximate the facts:

> 50 percent of the scientists in one grade have as many publications as or more publications than 25 percent of the scientists in the next higher grade.
>
> 25 percent of the scientists in one grade have as many publications as or more publications than 50 percent of the scientists in the next higher grade, and 25 percent of the scientists in the second higher grade.
>
> 10 percent of the scientists in one grade have as many publications as or more publications than 75 percent of the scientists in the next higher grade, 50 percent of the scientists in the second higher grade, and 25 percent of the scientists in the third higher grade.
>
> 3 percent of the scientists in one grade have as many publications as or more publications than 90 percent of the scientists in the next higher grade, 75 percent of the scientists in the second higher grade, 50 percent of the scientists in the third higher grade, and 25 percent of the scientists in the fourth higher grade.

The above relationships are brought out more clearly in table 7.

When scientists are separated by age, as in table 8, there is still a wide variation in the number of publications per scientist. Even at age 67 the spread is from 4 to 239 publications. It is apparent that the more prolific scientists produce a substantial proportion of the total publications. This is brought out even better in table 9 where the cumulative percentage of authors in decreasing publication rank order is compared with cumulative percentage of publications. Twenty percent of the authors produce half of the publications.

When quality of publications is considered along with quantity of publications to get a publication score, there is still a widespread difference between scientists of the same age. This is shown in table 10. (Total publication score = the summation of the products of publication credit (0.1 to 1.0) and rank order (1–100) for individual papers.) Over half of the scientists (1,594) had total publication scores of less than 300; 1,266 of these had scores under 200 and 806 had scores under 100; yet 9 scientists had scores over 3,000.

All scientists who had publications on which they were sole or senior author were asked to state the highest rank order they assigned to any one publication. The results are shown in tables 11 and 12. The range in highest rank order was from 1 to 100 with a mean of 53.

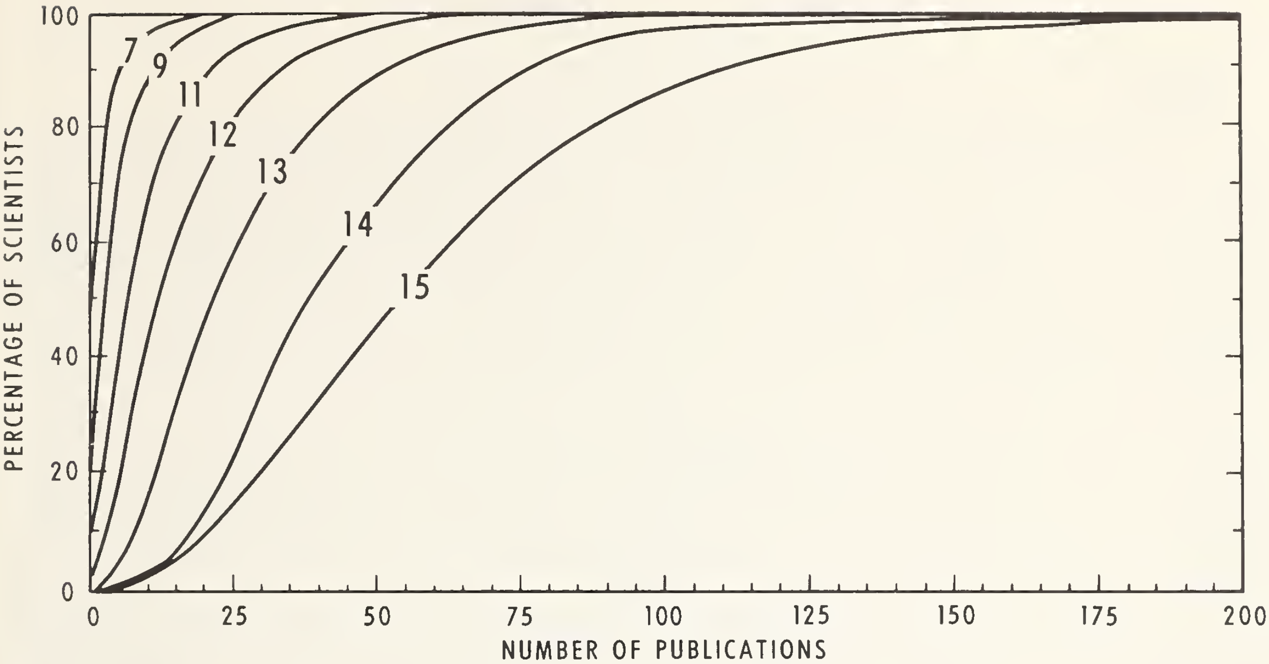

Figure 3.—Cumulative percentage of scientists, grades GS–7 to GS–15, having a given number or fewer publications.

Table 7.—*Number of publications not exceeded by the given percentage of scientists, by grade of scientist*

Percentage of scientists	Grade						
	7	9	11	12	13	14	15
97	11	20	34	48	73	115	155
90	5	11	21	33	51	75	110
75	2	6	11	21	35	57	80
50	1	3	7	12	21	38	53
25	0	1	3	7	13	26	34

Table 8.—*Number of scientists, by age, having a*

Number of publications [1]	Age, June 30, 1965																			
	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41
0 to 4	2	4	15	18	30	44	47	37	47	37	41	46	42	31	35	25	18	7	14	12
5 to 9	---	---	1	1	1	3	7	19	21	14	29	39	36	27	34	21	27	33	30	22
10 to 14	---	---	---	---	1	2	1	5	7	7	7	6	19	15	20	19	23	14	22	26
15 to 19	---	---	---	1	---	---	2	---	6	---	5	7	6	4	11	10	25	15	20	18
20 to 24	---	---	---	---	1	---	---	1	---	1	3	6	5	4	8	6	7	6	7	6
25 to 29	---	---	---	---	---	---	---	---	1	1	2	---	1	3	5	3	5	8	4	8
30 to 34	---	---	---	---	---	---	---	1	---	---	1	---	2	2	1	5	4	3	5	6
35 to 39	---	---	---	---	---	---	---	---	---	1	---	---	2	1	3	2	---	---	4	---
40 to 44	---	---	---	---	---	---	---	---	---	---	---	1	---	1	---	1	1	6	---	---
45 to 49	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	2	1	---	---
50 to 54	---	---	---	---	---	---	---	---	---	---	---	1	---	---	---	1	---	1	---	1
55 to 59	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1	2	---
60 to 64	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1	1	---	1	---	---
65 to 69	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1	1	---
70 to 74	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1	---	---	---	---	---
75 to 79	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1	---	---	---	---
80 to 84	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
85 to 89	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
90 to 94	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1
95 to 99	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
100 to 104	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
105 to 109	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
110 to 114	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
115 to 119	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
120 to 124	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
125 to 129	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
130 to 134	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
135 to 139	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
140 to 144	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
145 to 149	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
150 to 154	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
155 to 159	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
160 to 164	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
165 to 169	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
170 to 174	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
175 to 179	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
185 to 189	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
195 to 199	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
200 to 204	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
205 to 209	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
235 to 239	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
275 to 279	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---

[1] For total career of scientist regardless of employment.

given total number of publications to Jan. 1, 1965

Age, June 30, 1965—Continued																											
42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69
15	13	9	10	8	7	4	6	4	9	3	1	3	5	2	1	1	3	---	---	2	---	---	---	2	2	---	---
14	18	31	25	5	12	7	6	5	8	4	4	5	3	2	2	2	7	5	1	2	2	2	2	2	---	---	---
16	22	27	19	15	7	9	12	13	9	6	8	6	3	5	7	4	2	2	1	1	3	2	3	1	1	---	---
18	22	9	12	8	9	6	7	7	11	4	4	2	3	2	6	3	4	7	5	2	3	---	---	3	---	---	---
15	16	14	8	11	13	9	11	8	8	7	4	5	6	5	6	6	6	5	3	3	4	2	3	1	2	1	1
8	6	18	5	3	7	7	4	10	6	5	4	1	7	6	6	3	8	5	5	2	2	4	1	2	2	---	---
4	3	8	6	7	6	3	3	10	4	4	8	9	2	5	4	7	2	3	4	3	2	2	4	1	1	---	---
2	10	3	2	6	4	4	8	4	5	3	3	2	2	2	5	2	7	4	4	1	3	1	---	---	2	---	---
2	4	7	1	5	5	6	5	3	1	4	2	2	5	3	1	2	---	1	3	---	---	4	1	---	1	2	---
4	4	2	4	3	4	1	---	4	1	3	---	3	3	1	·3	3	6	4	1	5	2	1	1	2	1	2	1
1	1	5	3	4	1	2	---	---	5	3	2	---	4	2	2	2	4	2	3	1	---	2	2	---	---	1	---
1	1	---	---	3	3	1	---	2	4	2	2	1	1	2	1	1	2	1	3	1	---	2	---	1	1	1	1
---	---	1	3	1	---	1	3	2	2	4	2	1	1	3	3	1	---	3	---	1	1	---	2	1	---	---	---
2	2	---	---	---	1	---	5	1	---	5	1	1	3	---	2	---	2	4	1	1	1	1	---	---	1	---	1
---	---	---	---	---	2	2	---	2	2	---	2	2	---	1	1	4	---	2	1	1	1	---	2	---	1	---	---
---	---	---	---	---	1	2	---	---	1	---	1	2	2	1	---	---	3	1	---	---	---	---	---	---	1	---	1
---	---	---	---	---	---	2	2	1	---	---	1	1	---	3	---	---	---	3	1	---	---	3	1	---	---	---	---
---	1	---	---	---	---	---	1	---	---	---	---	2	---	1	---	---	1	1	3	---	---	---	---	1	---	---	---
---	---	---	---	---	---	1	---	---	2	---	---	---	---	---	---	---	2	1	1	1	1	---	2	---	1	---	---
---	---	---	---	---	---	1	---	---	---	---	---	---	3	---	2	1	---	---	1	---	---	---	---	---	1	---	---
---	---	1	---	---	---	---	1	---	---	---	---	---	1	1	---	---	---	---	---	---	---	1	---	1	1	---	---
---	---	---	---	---	---	1	---	---	2	---	---	---	---	---	---	1	---	---	1	---	---	---	---	1	---	1	---
---	---	---	---	---	---	1	---	---	---	---	1	---	1	---	1	---	---	---	---	---	---	---	---	---	---	---	---
---	---	---	---	---	---	---	---	---	1	---	1	---	---	---	---	---	1	---	---	---	---	---	---	---	---	---	---
---	---	1	1	---	---	---	---	---	---	---	---	---	---	1	---	---	---	---	---	1	---	---	---	---	---	---	1
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TABLE 9.—*Comparison of cumulative percentage of authors in decreasing publication rank order with cumulative percentage of publications*

Cumulative percentage of authors in decreasing publication rank order	Cumulative percentage of publications: All respondents	Cumulative percentage of publications: Respondents of the same age [1]	Cumulative percentage of authors in decreasing publication rank order	Cumulative percentage of publications: All respondents	Cumulative percentage of publications: Respondents of the same age [1]
5 percent	22	20	50 percent	87	80
10 percent	37	31	60 percent	92	87
15 percent	47	40	70 percent	96	93
20 percent	56	48	80 percent	98.5	97
30 percent	70	61	90 percent	99.8	99
40 percent	80	72	100 percent	100	100

[1] Calculated for ages 43, 48, 53, and 58, all of which showed the same relationship.

TABLE 10.—*Number of scientists, by age, having a*

Total publication score [1]	Age, June 30, 1965																			
	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41
0 to 99	2	4	14	13	27	44	45	42	56	38	49	53	51	38	44	24	29	21	26	18
100 to 199	----	----	----	----	1	1	4	14	11	7	15	24	23	23	24	26	21	22	17	23
200 to 299	----	----	----	1	----	1	----	1	4	4	6	10	11	6	13	15	17	13	18	20
300 to 399	----	----	----	----	----	----	----	1	2	----	3	----	7	4	13	10	13	9	20	12
400 to 499	----	----	----	----	----	----	----	----	----	1	----	2	5	2	6	5	9	6	8	10
500 to 599	----	----	----	----	----	----	----	----	----	----	----	----	3	1	2	3	5	3	4	3
600 to 699	----	----	----	----	----	----	----	----	----	----	----	1	----	1	1	3	1	5	1	4
700 to 799	----	----	----	----	1	----	----	----	----	----	----	----	----	----	1	1	1	3	1	2
800 to 899	----	----	----	----	----	----	----	----	----	----	----	----	1	1	----	1	2	----	----	1
900 to 999	----	----	----	----	----	----	----	----	----	----	----	----	----	1	----	----	1	1	1	----
1,000 to 1,099	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	1	----	----
1,100 to 1,199	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	1	----
1,200 to 1,299	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
1,300 to 1,399	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
1,400 to 1,499	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
1,500 to 1,599	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
1,600 to 1,699	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
1,700 to 1,799	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
1,800 to 1,899	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
1,900 to 1,999	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
2,000 to 2,099	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
2,100 to 2,199	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
2,200 to 2,299	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
2,300 to 2,399	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
2,400 to 2,499	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
2,500 to 2,599	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
2,600 to 2,699	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
2,700 to 2,799	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
2,800 to 2,899	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
2,900 to 2,999	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
3,000 to 3,099	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
3,100 to 3,199	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
3,200 to 3,299	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
3,300 to 3,399	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
3,400 to 3,499	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
3,500 to 3,599	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
3,600 to 3,699	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
3,700 to 3,799	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----

[1] For total career of scientist regardless of employment.

given total publication score to Jan. 1, 1965

Age, June 30, 1965—Continued																											
42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69
21	17	22	17	5	11	9	10	7	10	5	3	9	4	3	1	1	5	---	1	2	---	---	1	2	2	---	---
18	22	21	21	14	8	10	10	7	10	8	8	---	7	4	5	4	7	4	1	3	3	3	2	3	---	---	1
12	24	22	12	13	15	5	9	8	10	8	7	3	4	3	5	7	5	4	1	4	2	3	1	---	---	1	---
11	12	14	8	9	6	5	6	7	12	6	5	3	5	3	4	4	6	7	5	2	3	2	1	4	2	1	---
8	11	20	11	10	6	2	6	6	2	3	3	3	4	3	5	4	2	6	5	---	4	---	---	1	3	---	---
5	5	9	1	5	7	6	5	5	5	6	6	5	5	4	3	3	3	2	6	3	---	2	5	---	1	1	---
7	3	7	7	7	7	5	4	11	3	3	---	1	3	---	7	2	4	2	5	3	4	1	1	1	3	---	---
4	5	7	4	4	3	5	1	3	3	5	---	2	2	5	1	5	6	3	3	2	2	2	1	1	2	1	---
1	2	---	1	2	5	---	2	7	3	---	1	2	3	4	2	2	5	1	1	2	---	1	2	---	2	---	1
1	3	---	1	2	2	4	3	4	2	3	2	3	2	1	2	1	1	4	2	1	---	---	---	1	---	---	---
3	3	1	3	1	2	1	6	1	3	4	---	4	1	1	1	1	4	2	4	---	1	---	1	---	2	1	1
2	1	---	---	---	1	---	1	1	2	---	---	---	3	3	1	3	2	2	1	1	3	2	1	1	---	---	---
---	1	2	1	1	1	1	3	---	3	2	2	1	---	---	2	1	1	2	---	---	1	1	---	---	2	---	---
---	1	---	---	1	1	1	1	2	1	1	1	3	1	1	4	---	1	---	---	1	---	1	2	---	---	1	---
---	1	1	1	---	---	1	---	---	3	---	4	1	2	3	3	1	1	3	1	1	---	3	2	1	---	1	---
---	1	---	2	---	---	---	1	---	1	1	3	---	1	---	---	1	1	---	---	1	---	---	---	---	1	---	---
---	---	---	---	---	---	1	---	---	---	1	1	1	1	---	2	---	---	2	---	---	---	1	1	---	---	---	---
---	1	---	---	---	---	1	1	1	---	---	---	---	1	1	---	---	---	1	1	---	---	---	---	---	1	---	---
---	---	---	---	---	---	1	---	---	---	---	---	1	1	---	1	---	1	1	1	---	---	1	---	---	---	---	---
---	---	---	1	---	1	---	---	2	---	---	---	2	1	2	---	---	1	1	---	2	1	---	---	---	---	---	---
---	---	---	2	---	1	---	---	---	1	1	---	---	---	1	---	---	2	1	---	---	---	---	1	---	---	1	---
---	---	---	---	---	---	1	---	---	---	---	---	---	1	1	---	---	1	1	1	---	1	---	---	---	1	---	---
---	---	---	---	---	---	---	---	---	---	---	---	---	---	2	2	---	---	---	1	---	---	1	---	---	---	---	---
---	---	---	---	---	---	---	---	---	---	---	---	---	---	1	---	---	---	1	1	---	1	---	---	1	---	---	---
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1	---	---	---	---	---	---	---	---	---	---	1
---	---	---	---	---	---	---	---	---	---	---	1	---	---	---	---	1	---	---	---	---	---	---	---	1	---	---	---
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1	---	---	1	---	---	---	---	---	---	---	---
---	---	---	---	---	---	---	1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1	---	---	---	---	---	---	---	---	---	---
---	---	---	---	---	---	---	---	---	1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1	---	---	---	2	---	---	---	---	---	---	---
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1	---	---	---	---	---
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---
---	---	---	---	---	---	---	---	---	---	---	---	---	1	---	---	---	---	---	---	---	---	---	---	---	---	---	---
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1	---	---	---	---	---	---	---	---	---	---	---	---
---	---	---	---	---	---	---	---	---	---	---	---	---	1	---	---	---	---	---	---	---	1	---	---	---	---	---	---
---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1	---	---	---	---	---	---	---

TABLE 11.—*Number of scientists having a given highest rank order on sole or senior author papers, total and by grade*

Rank order	Grade							Total	Cumulative total
	7	9	11	12	13	14	15		
1 to 10	2	10	13	2	6			33	33
11 to 20	5	15	45	21	12	2	3	103	136
21 to 30	1	20	68	63	29	12	4	197	333
31 to 40	1	37	88	119	57	23	14	339	672
41 to 50	5	43	123	201	131	40	25	568	1, 240
51 to 60	3	38	99	198	167	85	36	626	1, 866
61 to 70		9	45	77	80	57	37	305	2, 171
71 to 80		9	20	64	83	64	43	283	2, 454
81 to 90		4	9	14	20	11	15	73	2, 527
91 to 100			4	2	9	1	5	21	2, 548
Total	17	185	514	761	594	295	182	2, 548	

TABLE 12.—*Cumulative percent of scientists by grade having a given highest rank order or less on sole or senior author papers, by grade*

Rank order	Grade							Total
	7	9	11	12	13	14	15	
1 to 10	11. 8	5. 4	2. 5	0. 3	1. 0			1. 3
11 to 20	41. 2	13. 5	11. 3	3. 0	3. 0	0. 7	1. 7	5. 3
21 to 30	47. 1	24. 3	24. 5	11. 3	7. 9	4. 8	3. 9	13. 1
31 to 40	52. 9	44. 3	41. 6	26. 9	17. 5	12. 6	11. 5	26. 4
41 to 50	82. 3	67. 6	65. 6	53. 4	39. 6	26. 1	25. 3	48. 7
51 to 60	100. 0	88. 1	84. 8	79. 4	67. 7	54. 9	45. 1	73. 2
61 to 70		93. 0	93. 6	89. 5	81. 1	74. 2	65. 4	85. 2
71 to 80		97. 8	97. 5	97. 9	95. 1	95. 9	89. 0	96. 3
81 to 90		100. 0	99. 2	99. 7	98. 5	99. 7	97. 3	99. 2
91 to 100			100. 0	100. 0	100. 0	100. 0	100. 0	100. 0

Publication score per year is a better measure than total publication score to use in comparing scientists, since publication score per year eliminates the length-of-experience variable. Tables 13, 14, and 15 and figure 4 give number and percentage of scientists by grade having a given publication score per year. Again, there is a wide variation among scientists, but most of the spread is caused by about 10 percent of the scientists. Ninety percent of the scientists have scores per year of 60 or less, whereas the highest score per year is 250.

The relationships among grades in number of publications shown in table 7 hold even better with publication score per year; these relationships are brought out in table 16.

It would appear that the following relationships between publication score per year to January 1, 1965, and the percentage of scientists in different grades approximate the facts:

50 percent of the scientists in one grade have a publication score per year as high as or higher than 25 percent of the scientists in the next higher grade.

25 percent of the scientists in one grade have a publication score per year as high as or higher than 50 percent of the scientists in the next higher grade and 25 percent of the scientists in the second higher grade.

10 percent of the scientists in one grade have a publication score per year as high as or

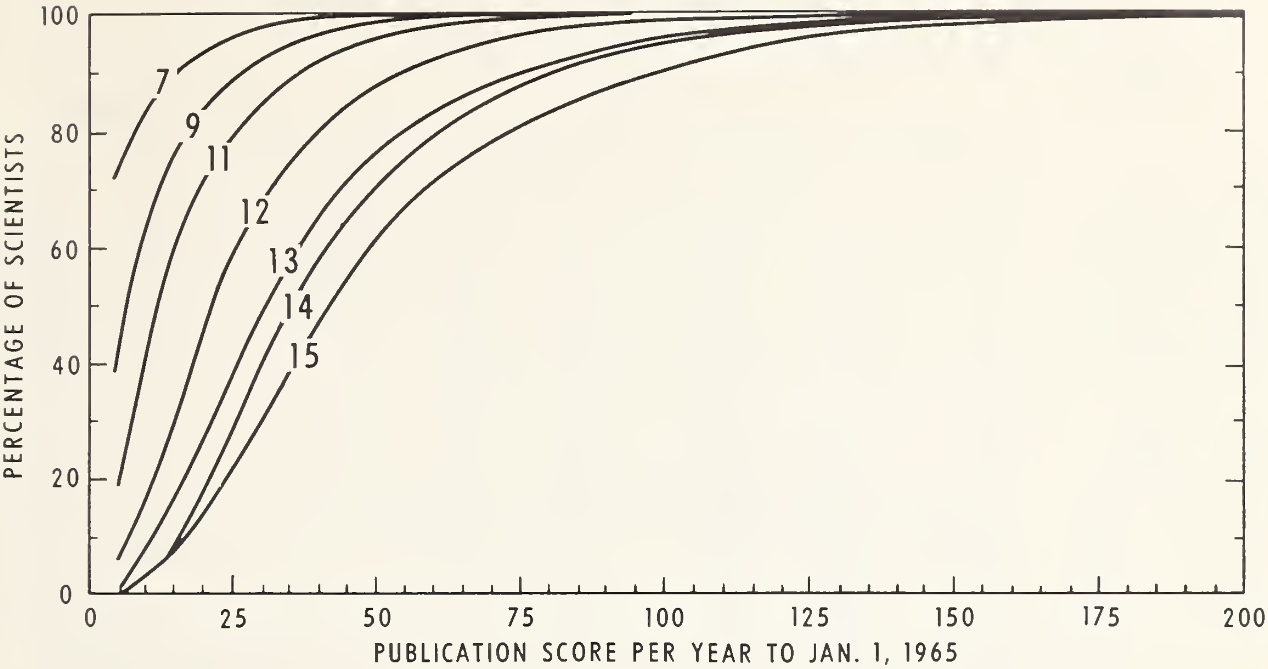

FIGURE 4.—Cumulative percentage of scientists, grades GS–7 to GS–15, having a given publication score or less per year.

TABLE 13.—*Number of scientists having a given publication score per year, total and by grade*

Publication score per year	Grade							Total	Cumulative total
	7	9	11	12	13	14	15		
0 to 5	107	128	115	44	12	2	1	409	--------
5+ to 10	18	76	133	88	37	8	5	365	774
10+ to 15	9	45	110	113	52	16	10	355	1, 129
15+ to 20	7	28	84	118	73	35	10	355	1, 484
20+ to 25	3	13	46	100	65	34	15	276	1, 760
25+ to 30	3	15	34	79	61	27	13	232	1, 992
30+ to 35	1	8	22	69	55	25	20	200	2, 192
35+ to 40	--------	6	26	48	37	30	8	155	2, 347
40+ to 45	--------	3	10	45	38	20	16	132	2, 479
45+ to 50	1	2	9	21	43	21	16	113	2, 592
50+ to 55	--------	--------	5	15	23	7	15	65	2, 657
55+ to 60	--------	1	7	17	23	19	4	71	2, 728
60+ to 65	1	1	7	17	10	10	8	54	2, 782
65+ to 70	--------	1	3	15	13	10	6	48	2, 830
70+ to 75	--------	--------	1	7	10	4	2	24	2, 854
75+ to 80	--------	1	--------	2	6	5	5	19	2, 873
80+ to 85	--------	--------	2	5	5	3	5	20	2, 993
85+ to 90	--------	1	2	8	7	7	4	29	2, 922
90+ to 95	--------	--------	2	4	8	6	3	23	2, 945
95+ to 100	--------	--------	--------	2	8	--------	1	11	2, 956

TABLE 13.—*Number of scientists having a given publication score per year, total and by grade*—Con.

Publication score per year	Grade							Total	Cumulative total
	7	9	11	12	13	14	15		
100+ to 105				2	4	2	5	13	2, 969
105+ to 110				1	4	3	1	9	2, 978
110+ to 115					1	1	1	3	2, 981
115+ to 120					5		1	6	2, 987
120+ to 125					4		2	6	2, 993
125+ to 130					2	1		3	2, 996
130+ to 135				1	2		2	5	3, 001
135+ to 140					2	1	3	6	3, 007
140+ to 145				1	1	2		4	3, 011
145+ to 150					1			1	3, 012
150+ to 175					3	2	2	7	3, 019
175+ to 200				2		2		4	3, 023
200+ to 250							2	2	3, 025
Total	150	329	618	824	615	303	186	3, 025	

TABLE 14.—*Percent of scientists having a given publication score per year, total and by grade*

Publication score per year	Grade							Total
	7	9	11	12	13	14	15	
0 to 5	71. 33	38. 91	18. 61	5. 34	1. 95	0. 66	0. 54	13. 52
5+ to 10	12. 00	23. 10	21. 52	10. 68	6. 02	2. 64	2. 69	12. 07
10+ to 15	6. 00	13. 68	17. 80	13. 71	8. 46	5. 28	5. 38	11. 74
15+ to 20	4. 67	8. 51	13. 59	14. 32	11. 87	11. 55	5. 38	11. 74
20+ to 25	2. 00	3. 95	7. 44	12. 14	10. 57	11. 22	8. 06	9. 12
25+ to 30	2. 00	4. 56	5. 50	9. 59	9. 92	8. 91	6. 99	7. 67
30+ to 35	. 67	2. 43	3. 56	8. 37	8. 94	8. 25	10. 75	6. 61
35+ to 40		1. 82	4. 21	5. 83	6. 02	9. 90	4. 30	5. 12
40+ to 45		. 91	1. 62	5. 46	6. 18	6. 60	8. 60	4. 36
45+ to 50	. 67	. 61	1. 46	2. 55	6. 99	6. 93	8. 60	3. 74
50+ to 55			. 81	1. 82	3. 74	2. 31	8. 06	2. 15
55+ to 60		. 30	1. 13	2. 06	3. 74	6. 27	2. 15	2. 35
60+ to 65	. 67	. 30	1. 13	2. 06	1. 63	3. 30	4. 30	1. 79
65+ to 70		. 30	. 49	1. 82	2. 11	3. 30	3. 23	1. 59
70+ to 75			. 16	. 85	1. 63	1. 32	1. 08	. 79
75+ to 80		. 30		. 24	. 98	1. 65	2. 69	. 63
80+ to 85			. 32	. 61	. 81	. 99	2. 69	. 66
85+ to 90		. 30	. 32	. 97	1. 14	2. 31	2. 15	. 96
90+ to 95			. 32	. 49	1. 30	1. 98	1. 61	. 76
95+ to 100				. 24	1. 30		. 54	. 36
100+ to 105				. 24	. 65	. 66	2. 69	. 43
105+ to 110				. 12	. 65	. 99	. 54	. 30
110+ to 115					. 16	. 33	. 54	. 10
115+ to 120					. 81		. 54	. 20
120+ to 125					. 65		1. 08	. 20
125+ to 130					. 33	. 33		. 10
130+ to 135				. 12	. 33		1. 08	. 17
135+ to 140					. 33	. 33	1. 61	. 20
140+ to 145				. 12	. 16	. 66		. 13
145+ to 150					. 16			. 03
150+ to 175					. 49	. 66	1. 08	. 23
175+ to 200				. 24		. 66		. 13
200+ to 250							1. 08	. 07

TABLE 15.—*Cumulative percent of scientists having a given publication score or less per year, total and by grade*

Publication score per year	Grade							Total
	7	9	11	12	13	14	15	
0 to 5	71.33	38.91	18.61	5.34	1.95	0.66	0.54	13.52
5+ to 10	83.33	62.01	40.13	16.02	7.97	3.30	3.23	25.59
10+ to 15	89.33	75.69	57.93	29.73	16.43	8.58	8.61	37.33
15+ to 20	94.00	84.20	71.52	44.05	28.30	20.13	13.99	49.07
20+ to 25	96.00	88.15	78.96	56.19	38.87	31.35	22.05	58.19
25+ to 30	98.00	92.71	84.46	65.78	48.79	40.26	29.04	65.86
30+ to 35	98.67	95.14	88.02	74.15	57.73	48.51	39.79	72.47
35+ to 40		96.96	92.23	79.98	63.75	58.41	44.09	77.59
40+ to 45		97.87	93.85	85.44	69.93	65.01	52.69	81.95
45+ to 50	99.34	98.48	95.31	87.99	76.92	71.94	61.29	85.69
50+ to 55			96.12	89.81	80.66	74.25	69.35	87.84
55+ to 60		98.78	97.25	91.87	84.40	80.52	71.50	90.19
60+ to 65	100.00	99.08	98.38	93.93	86.03	83.82	75.80	91.98
65+ to 70		99.38	98.87	95.75	88.14	87.12	79.03	93.57
70+ to 75			99.03	96.60	89.77	88.44	80.11	94.36
75+ to 80		99.68		96.84	90.75	90.09	82.80	94.99
80+ to 85			99.35	97.45	91.56	91.08	85.49	95.65
85+ to 90		100.00	99.67	98.42	92.70	93.39	87.64	96.61
90+ to 95			100.00	98.91	94.00	95.37	89.25	97.37
95+ to 100				99.15	95.30		89.79	97.73
100+ to 105				99.39	95.95	96.03	92.48	98.16
105+ to 110				99.51	96.60	97.02	93.02	98.46
110+ to 115					96.76	97.35	93.56	98.56
115+ to 120					97.57		94.10	98.76
120+ to 125					98.22		95.18	98.96
125+ to 130					98.55	97.68		99.06
130+ to 135				99.63	98.88		96.26	99.23
135+ to 140					99.21	98.01	97.87	99.43
140+ to 145				99.75	99.37	98.67		99.56
145+ to 150					99.53			99.59
150+ to 175					100.00	99.33	98.95	99.82
175+ to 200				100.00		100.00		99.95
200+ to 250							100.00	100.00

TABLE 16.—*Publication score per year to Jan. 1, 1965, not exceeded by the given percentage of scientists, by grade of scientist*

Percentage of scientists	Grade						
	7	9	11	12	13	14	15
97	26	40	55	77	115	110	138
90	15	26	36	53	75	80	97
75	6	15	22	35	48	54	65
50	5	7	12	22	31	35	41
25	0	5	7	13	19	23	27

higher than 75 percent of the scientists in the next higher grade, 50 percent of the scientists in the second higher grade, and 25 percent of the scientists in the third higher grade.

3 percent of the scientists in one grade have a publication score per year as high as or higher than 90 percent of the scientists in the next higher grade, 75 percent of those in the second higher grade, 50 percent of those in the third higher grade, and 25 percent of those in the fourth higher grade.

The mean number of publications and the mean publication score of scientists by age of scientist is given in table 17. While there was wide variation among individual scientists in number of publications and publication scores as shown above, the means for each age group show a somewhat regular increase with age.

In table 17 and tables to follow, the numbers of scientists used in calculating means of publication scores differ from the numbers used in calculating means of publication numbers. Responses from scientists reporting publication score per year in excess of those shown in tabulation below were not used in calculating mean publication scores. They were not used because a few very high responses made the means unrepresentative of the group. For example, if all responses for grade 7 were used in calculating the mean publication score per year, the mean would be 4.9, whereas using 124 responses the mean was 1.8. The effect of leaving out a few high responses was to make the mean and median responses about the same.

The following are the maximum publication scores per year to January 1, 1965, used in calculating the means:

Grade of scientist	*Maximum score*
7	10
9	20
11	40
12	60
13	80
14	100
15	120

Table 17.—*Mean number of publications and mean publication score to Jan. 1, 1965, by age of scientist*

Age June 30, 1965	Number of scientists	Mean number of publications	Number of scientists	Mean publication score
22	2	0	2	0
23	4	0	4	0
24	16	1. 1	14	5
25	20	1. 9	14	28
26	33	2. 2	29	44
27	49	1. 7	46	24
28	57	3. 0	49	40
29	63	4. 9	58	76
30	82	5. 2	73	72
31	61	5. 7	50	81
32	88	6. 7	73	91
33	106	7. 0	90	106
34	113	8. 1	101	148
35	88	8. 9	77	149
36	119	11. 2	104	175
37	95	13. 3	88	220
38	112	13. 2	99	244
39	97	16. 8	84	269
40	109	14. 4	97	250
41	100	14. 8	93	266
42	102	18. 5	93	338
43	124	21. 3	113	386
44	136	20. 5	126	342
45	99	19. 2	93	422
46	79	24. 3	74	408
47	82	25. 2	77	478
48	70	32. 7	59	556
49	74	29. 9	70	540
50	76	27. 2	72	569
51	83	33. 2	75	558
52	58	34. 6	57	558
53	52	37. 6	47	653
54	48	33. 7	44	706
55	57	45. 9	54	800
56	50	44. 0	46	889
57	54	36. 8	52	843
58	46	42. 9	44	780
59	61	38. 1	60	737
60	54	39. 8	50	851
61	42	44. 1	42	852
62	31	51. 4	31	951
63	28	45. 1	27	878
64	29	52. 5	25	975
65	24	41. 8	22	836
66	19	36. 7	17	713
67	22	62. 6	22	808
68	8	51. 8	8	976
69	6	65. 2	4	1, 108

Publication Records of ARS Scientists as Related to Grade, Degree, Position Title, Length of Experience, Work Location, and Place of Previous Employment

Grade

Publication records of ARS scientists by grade are given in table 18. As expected, there is a significant increase from grade to grade with one exception regardless of the publication measure used. Mean publication credit per year is not significantly different for grades 13 and 14. The scientists in grade 15 produce about twice as many publications per year and have a publication score per year about twice as big as the scientists in grade 12.

Degree

A comparison of publication records of ARS scientists having different degrees is shown in table 19. Those scientists having doctor's degrees have 1.35 times the publications per year, 1.55 times the publication credit per year, and 1.53 times the publication score per year as those having master's degrees. For all respondents, the mean number of publications per year was 1.3 for all the years they have been publishing.

Position Title

The publication records of ARS scientists by position titles on January 1, 1965, are given in table 20. To find that scientists having the position title "Research Scientist" had the lowest publications per year was somewhat of a surprise. Looking into this, it was soon apparent what the reasons were. All employees in grade 7 and most of those in grades 9 and 11 were listed as research scientists, whereas the grades of people with other position titles were nearly all grade 12 and above, as shown in table 21. For this reason, table 22 was prepared using responses for only those scientists who were in grades 12 and above. Here, the record of "Research Scientists" looks somewhat better. Scientists having the position titles "Investigations Leader" and "Laboratory Chief"

TABLE 18.—*Means of publication records of ARS scientists to Jan. 1, 1965, and number of respondents used in calculating the means, by grade of scientist* [1]

Item	Grade						
	7	9	11	12	13	14	15
Number of respondents	149	328	614	820	614	303	185
Publications:							
Total, mean	1. 960	4. 896	9. 836	16. 310	27. 399	44. 584	63. 151
Per year, mean	. 327	. 651	. 914	1. 315	1. 695	2. 004	2. 443
Publication credit:							
Total, mean	. 638	2. 096	5. 047	9. 995	16. 901	26. 361	36. 936
Per year, mean	. 114	. 288	. 485	. 813	1. 140	1. 227	1. 474
Number of respondents [2]	124	276	566	752	556	288	175
Publication score:							
Total, mean	13. 202	52. 116	149. 816	293. 914	516. 763	861. 726	1, 187. 269
Per year, mean	1. 814	6. 657	13. 588	23. 080	31. 559	38. 150	45. 714

[1] Any 2 means not underscored by the same line are significantly different at less than the 1-percent level. Any 2 means underscored by the same line are not significantly different at the 5-percent level.

[2] Certain high responses were not used in calculations relating to publication scores. See p. 22.

have significantly more publications per year and significantly higher publication scores per year than scientists having other position titles.

Table 23 compares the publication records of scientists in grades 12 through 15 who have the position title "Research Scientist." Those in grade 15 have records more than double those of scientists in grade 12.

Length of Experience

Scientists' publication records are compared in table 24 in relation to the length of time they have been publishing. Scientists who have been publishing 21 or more years have significantly better records than those who have published 20 years or less. There is no indication that a scientist reaches a maximum rate of publication in early

TABLE 19.—*Means [1] of publication records to Jan. 1, 1965, of ARS scientists having specified degrees on Jan. 1, 1965, and number of respondents used in calculating the means*

Item	Ph. D., Sc. D.	M.S., M.A., D.V.M.	B.S., B.A.	No degree	All respondents
Number of respondents	1, 346	841	802	39	3, 028
Number of publications per year, mean [1]	1. 680	1. 244	0. 889	0. 746	1. 335
Publication credit per year, mean [1]	1. 097	. 707	. 451	. 334	. 808
Number of respondents [2]	1, 217	768	734	34	2, 753
Publication score per year, mean [1]	31. 367	20. 439	13. 847	12. 206	23. 408

[1] Any 2 means not underscored by the same line are significantly different at the 1-percent level.

[2] Certain high responses were not used in calculations relating to publication scores. See p. 22.

TABLE 20.—*Means [1] of publication records to Jan. 1, 1965, of ARS scientists by position title on Jan. 1, 1965, and number of respondents used in calculating the means*

Item	Research scientist	Field station superintendent	Project leader	Division director	Laboratory director	Branch chief	Investigations leader	Laboratory chief
Number of respondents	2, 069	49	360	70	26	73	326	54
Number of publications per year, mean	1. 171	1. 385	1. 395	1. 558	1. 615	1. 656	2. 008	2. 405
Publication credit per year, mean	. 694	. 761	. 899	. 934	1. 095	1. 108	1. 247	1. 239
Number of respondents [2]	1, 847	47	328	70	26	71	312	51
Publication score per year, mean	20. 149	19. 032	24. 139	28. 319	[3] 30. 438	27. 600	[3] 37. 253	40. 494

[1] Any 2 means not underscored by the same line are significantly different at the 5 percent level, except as noted in footnote 3.

[2] Certain high responses were not used in calculations relating to publication scores. See p.22.

[3] 30.438 is not significantly different from 37.253.

years and then has a reduced rate in later years as some have suggested (*2, 3, 6*). On the contrary, the data in table 24 confirm the findings of Stewart and Sparks (*8*) that productivity increases with age. The publication records of the four scientists producing the highest number of publications per year in grades 12, 13, 14, and 15 were examined in more detail.

In grade 12 the range in publications per year went from 0 to 6.6. The scientist who produced 6.6 publications per year had a total of 236 publications. He has been publishing 36 years. During the first 26 years he published 153 papers, or 5.9 publications per year. During the last 10 years he published 83 papers, a per-year rate of 8.3.

TABLE 21.—*Number of ARS scientists having a given position title, by grade*

Grade	Research scientist	Project leader	Investigations leader	Laboratory director	Field station superintendent	Laboratory chief [1]	Branch chief [1]	Division director [1]
7	149							
9	310	15	2		1			
11	540	58	3	1	7	1	1	2
12	640	128	28	1	16	1	1	5
13	330	128	99	8	21	2	14	12
14	75	31	136	10	4	13	28	6
15	24		57	6		35	29	34
16						2		9
17			1					2
18	1							
Total	2, 069	360	326	26	49	54	73	70

[1] All scientists in the Office of Chief or Director.

TABLE 22.—*Means of publication records to Jan. 1, 1965, of ARS scientists grade 12 and above, by position title, and number of respondents used in calculating means*

Item	Field station superintendent	Project leader	Branch chief	Division director	Laboratory director	Research scientist	Investigations leader	Laboratory chief
Number of respondents	49	287	73	70	26	1, 070	326	54
Number of publications per year, mean [1]	1. 385	1. 562	1. 656	1. 558	1. 615	1. 579	2. 008	2. 405
Number of respondents	47	266	71	70	26	963	312	51
Publication score per year, mean [2]	19. 032	26. 725	27. 600	28. 319	[3] 30. 438	29. 572	[3] 37. 253	[3] 40. 494

[1] Any 2 means not underscored by the same line are significantly different at the 5-percent level.

[2] Any 2 means not underscored by the same line are significantly different at the 1-percent level except as noted in footnote 3.

[3] 30.438 is not significantly different from 37.253 at the 5-percent level and is significantly different from 40.494 at the 5-percent level.

TABLE 23.—*Means of publication records to Jan. 1, 1965, of ARS "Research scientists," by grade, and number of respondents used in calculating the means*

Item	Grade 12	Grade 13	Grade 14	Grade 15
Number of respondents	640	330	75	24
Number of publications per year, mean [1]	1.330	1.782	2.347	2.942
Number of respondents	588	292	61	21
Publication score per year, mean [1]	24.015	34.776	46.766	60.086

[1] Any 2 means not underscored by the same line are significantly different at the 1-percent level. 46.766 and 60.086 are significantly different at the 5-percent level.

In grade 13 the range in publications per year went from 0 to 6.7. The scientist who produced 6.7 publications per year had a total of 209 publications. He has been publishing 31 years. During the first 21 years he published 130 papers with a per-year rate of 6.2. During the last 10 years he published 79 papers with a per-year rate of 7.9.

In grade 14 the range in publications per year went from 0.9 to 10.4. The scientist who produced 10.4 publications per year had a total of 187 publications. He has been publishing 18 years. During the first 8 years he produced 60 publications, a per-year rate of 7.5. During the last 10 years he published 127 papers, a per-year rate of 12.7.

In grade 15 the range in publications per year went from 1.1 to 9.6. The scientist producing 9.6 publications per year had a total of 278 publications. He has been publishing 29 years. During the first 19 years he published 135 papers, a per-year rate of 7.1. During the last 10 years he published 143 papers, a per-year rate of 14.3.

Work Location

The publication records of scientists located on or near (10 miles) a college campus are compared with scientists located more than 10 miles from a college campus in table 25. The publication records were not significantly different.

ARS scientists working in cooperator facilities produced more publications per year than those working in Federal facilities, as shown in table 26.

TABLE 24.—*Means of publication records to Jan. 1, 1965, of ARS scientists, by length of time they have been publishing, and number of respondents used in calculating the means*

Item	31 or more years	21 to 30 years	11 to 20 years	0 to 10 years
Number of respondents	247	407	904	1,460
Number of publications per year, mean [1]	1.684	[2] 1.675	[2] 1.507	1.089
Publication credit per year, mean [1]	1.069	.985	.943	.636
Number of respondents [3]	234	385	835	1,289
Publication score per year, mean [1]	31.586	31.187	26.822	17.576

[1] Any 2 means not underscored by the same line are significantly different at the 1-percent level, except as noted in footnote 2.

[2] 1.507 is significantly different from 1.675 at the 5-percent level.

[3] Certain high responses were not used in calculations relating to publication scores. See p. 22.

TABLE 25.—*Publication records to Jan. 1, 1965, of ARS scientists located on or near (10 miles) a college campus and those more than 10 miles from a campus*

Item	Mean		Difference in means	Number of respondents	
	On or near campus	Off campus		On or near campus	Off campus
Publications per year	1.325	1.411	[1] 0.086	2,458	544
Publication credit per year	.791	.875	[1] .084	2,458	544
Publication score per year	23.495	23.273	[1] .222	[2] 2,249	[2] 481

[1] Not significantly different at 5-percent level.

[2] Certain high responses were not used in calculations relating to publication scores. See p. 22.

The publication scores per year were not significantly different.

When both ownership of facilities and work location were considered, as in table 27, it turns out that scientists in cooperator facilities located off campus produced the greatest number of publications per year, but had the lowest publication score per year. However, the publication scores per year were not significantly different for any comparison.

While not many means in tables 25, 26, and 27 were significantly different, those that were tend to favor scientists working in cooperator facilities and those located off campus. It turns out that these differences are not due to work location or ownership of facilities in which the scientists work, but rather to the differences in average degrees of the scientists working in the different situations, as shown in tables 28, 29, and 30. It must be concluded that scientists with the same training and experience produce as well in one situation as another. This is contrary to the general belief that working on a college campus leads to higher productivity.

TABLE 26.—*Means of publication records to Jan. 1, 1965, of ARS scientists working in Federal (F) facilities and cooperator (C) facilities, difference in means, and number of respondents used in calculating the means*

Item	Mean		Difference in means	Number of respondents	
	F	C		F	C
Publications per year	1. 302	1. 485	**0. 183	2, 374	640
Publication credit per year	. 754	. 952	**. 198	2, 374	640
Publication score per year	23. 227	24. 367	[1] 1. 140	[2] 2, 172	[2] 568

**Significantly different at 1-percent level.
[1] Not significantly different at 5-percent level.
[2] Certain high responses were not used in calculations relating to publication scores. See p. 22.

TABLE 27.—*Range and mean of publication records to Jan. 1, 1965, of ARS scientists working in Federal and cooperator facilities, on and off campus, and number of respondents*

Item	Federal facilities		Cooperator facilities	
	On or near campus [1]	Off campus	Off campus	On or near campus [1]
Number of respondents	1, 955	407	137	503
Number of publications per year:				
Range	10–0	7–0	9. 6–0	9. 9–0
Mean [2]	1. 287	1. 374	1. 523	1. 475
Publication credit per year:				
Range	([3])	([3])	7. 1–0	7. 6–0
Mean [2]	. 749	. 853	. 939	. 955
Number of respondents [4]	1, 800	362	119	449
Publication score per year:				
Range	117–0	110–0	80–0	88–0
Mean [2]	23. 142	23. 586	22. 321	24. 909

[1] Within 10 miles.
[2] Any 2 means not underscored by the same line are significantly different at the 5-percent level.
[3] Not available.
[4] Certain high responses were not used in calculations relating to publication scores. See p. 22.

Publication Records Before and After Entering ARS

Those scientists who had been continuously employed by ARS since January 1, 1955, and who had previous full-time employment in research or research and teaching improved their publication records after joining ARS without regard to their place of previous employment, as shown in table 31. However, when one takes account of differences in publication records as related to length of experience for all ARS scientists in table 24 and for those continuously employed since January 1, 1955, in table 32, it is apparent that most of the differences shown in table 31 are due to the additional years of experience.

TABLE 28.—*Average degree, average grade, and average length of experience of ARS scientists working on and off campus*

Item	On campus [1]	Off campus
Average degree [2]	3. 14	3. 21
Average grade	11. 85	11. 81
Average length of experience (years)	13. 25	12. 55

[1] On or near (10 miles).
[2] Rating:
Doctors—4;
Masters—3;
Bachelors—2;
No degree—1.

TABLE 29.—*Average degree, average grade, and average length of experience of ARS scientists working in Federal and cooperator facilities*

Item	Cooperator facilities	Federal facilities
Average degree [1]	3. 42	3. 08
Average grade	11. 86	11. 83
Average length of experience (years)	12. 27	13. 36

[1] Rating:
Doctors—4;
Masters—3;
Bachelors—2;
No degree—1.

TABLE 30.—*Average degree, average grade, and average length of experience of ARS scientists working in Federal and cooperator facilities, on and off campus*

Item	Federal facilities		Cooperator facilities	
	On campus [1]	Off campus	On campus [1]	Off campus
Average degree [2]	3. 07	3. 13	3. 41	3. 45
Average grade	11. 84	11. 80	11. 87	11. 83
Average length of experience (years)	13. 50	12. 65	12. 27	12. 25

[1] On or near (10 miles).
[2] Rating:
Doctors—4;
Masters—3;
Bachelors—2;
No degree—1.

Publications and Promotions

A major objective of this study was to find what relation, if any, there was between publications (number and quality) and promotions. Before the reorganization of ARS in 1954, scientists were in different bureaus having somewhat varying personnel policies. Since 1954, except for two divisions which joined ARS in 1964, scientists in ARS have been under uniform personnel policies. These policies have changed since 1954, but they have changed uniformly for all. Consequently, the period from January 1, 1955 to January 1, 1965 was selected as the best period to study the relation between publications and promotions. Only the responses from the 1,327 scientists continuously employed by ARS from January 1, 1955 to January 1, 1965 were considered in analyzing the relation between publications and promotions.

Correlation Between Promotions and Publications by Grade of Scientist

Correlation coefficients between the number of grade changes from January 1, 1955 and 18 publication measures by grade of scientists on January 1, 1955 are shown in table 33. The total number of publications before January 1, 1955, was not positively correlated with promotions, but number per year before January 1, 1955 was

TABLE 31.—*Publication record before and after entering ARS of scientists continuously employed by ARS since Jan. 1, 1955, who had previous full-time employment in research or research and teaching by place of previous employment*

Place of previous employment, number of scientists, and publication record	Mean		Difference in means
	Before	After	
University, 297 scientists			
Publications per year	1. 248	1. 895	**0. 647
Publication credit per year	. 805	1. 109	**. 304
Publication score per year	26. 269	35. 402	**9. 133
Industry, 66 scientists			
Publications per year	. 609	1. 475	**. 866
Publication credit per year	. 339	. 773	**. 434
Publication score per year	10. 575	27. 343	**16. 768
Federal Government, 72 scientists			
Publications per year	. 622	1. 333	**. 711
Publication credit per year	. 406	. 822	**. 416
Publication score per year	11. 976	22. 547	**10. 571
Other,[1] 85 scientists			
Publications per year	1. 086	1. 781	**. 695
Publication credit per year	. 677	1. 068	**. 391
Publication score per year	21. 990	33. 381	**11. 391
Total, 520 scientists			
Publications per year	. 891	1. 621	**. 730
Publication credit per year	. 556	. 943	**. 387
Publication score per year	17. 703	29. 668	**11. 965

**Significantly different at 1-percent level.
[1] Usually previously employed by two or more of the other three categories.

correlated with promotions in the following 10 years. Total publications between January 1, 1955 and January 1, 1965, total publications to January 1, 1965, publications per year between January 1, 1955, and January 1, 1965, and publications per year to January 1, 1965 were all highly correlated with promotions from January 1, 1955 to January 1, 1965.

The same relationships hold for publication credit and publication score as those given above for number of publications.

For the two time periods January 1, 1955 to January 1, 1965 and total to January 1, 1965, which show publications to be correlated with promotions, the per-year values were more highly correlated with promotions than total values were in 31 out of 36 comparisons in grades 5 through 13. Publication score per year was only slightly better correlated with promotions than publications per year—7 out of 12 comparisons in grades 5 through 13. Publication score per year was more highly correlated with promotions than publication credit per year in 9 out of 12 comparisons in grades 5 through 12.

TABLE 32.—*Mean and range of three publication measures to Jan. 1, 1955, and between Jan. 1, 1955, and Jan. 1, 1965, for the 1,327 scientists employed continuously by ARS since Jan. 1, 1955*

Item	Publications per year	Publication credit per year	Publication score per year
To Jan. 1, 1955			
Mean	1. 08	0. 64	19. 75
Maximum	7. 50	6. 10	143. 00
Minimum	0	0	0
Jan. 1, 1955, to Jan. 1, 1965			
Mean	1. 81	1. 04	32. 43
Maximum	14. 30	11. 90	164. 60
Minimum	0	0	0

TABLE 33.—*Correlation coefficients between number of grade changes from Jan. 1, 1955, to Jan. 1, 1965, and various publication measures, by grade of scientists on Jan. 1, 1955*

Publication measure	Grade, Jan. 1, 1955							
	5	7	9	11	12	13	14	All grades [1]
Total publications								
1. To Jan. 1, 1955	0.138	−0.019	−0.057	−0.082	0.111	0.126	0.084	**−0.154
2. Jan. 1, 1955 to Jan. 1, 1965	**.534	**.544	**.382	**.372	**.325	**.286	.068	**.190
3. To Jan. 1, 1965	**.551	**.355	**.251	**.178	**.255	*.234	.088	−.005
Publications per year								
4. To Jan. 1, 1955	*.269	**.204	**.189	*.134	**.232	*.217	.020	.007
5. Jan. 1, 1955 to Jan. 1, 1965	**.557	**.455	**.387	**.399	**.311	**.297	.068	**.200
6. To Jan. 1, 1965	**.623	**.443	**.412	**.350	**.308	**.279	.079	**.195
Publication credit								
7. To Jan. 1, 1955	.155	.072	−.036	−.083	.040	.098	−.084	**−.157
8. Jan. 1, 1955 to Jan. 1, 1965	**.480	**.479	**.312	**.261	**.218	**.270	.078	**.142
9. To Jan. 1, 1965	**.501	**.420	**.210	*.133	*.162	*.196	−.038	−.031
Publication credit per year								
10. To Jan. 1, 1955	.215	**.227	**.183	.111	*.128	*.198	−.101	−.010
11. Jan. 1, 1955 to Jan. 1, 1965	**.492	**.479	**.319	**.249	**.221	**.266	.075	**.143
12. To Jan. 1, 1965	**.575	**.229	**.343	**.227	**.195	*.247	−.038	**.132
Publication score								
13. To Jan. 1, 1955	.197	.017	−.017	.002	**.185	.101	.116	**−.121
14. Jan. 1, 1955 to Jan. 1, 1965	**.640	**.442	**.407	**.465	*.147	*.215	.263	**.087
15. To Jan. 1, 1965	**.593	**.355	**.196	**.283	**.276	.095	.192	.008
Publication score per year								
16. To Jan. 1, 1955	*.297	*.161	**.240	**.181	**.311	.177	.160	.023
17. Jan. 1, 1955 to Jan. 1, 1965	**.668	**.442	**.412	**.466	**.310	*.220	.264	**.221
18. To Jan. 1, 1965	**.667	**.428	**.437	**.426	**.361	*.219	.250	**.212
*Significant at 5-percent level	0.264	0.143	0.107	0.117	0.128	0.194	0.384	0.056
**Significant at 1-percent level	.344	.188	.141	.153	.170	.254	.496	.073

[1] Including grade 15.

As would be expected, the highest correlations between publication score per year and promotions were obtained for those employees who were in grade 5 on January 1, 1955. About equal correlations were found for those in grades 7, 9, and 11 on January 1, 1955. The lowest correlations were for those employees who were in grade 12 and above on January 1, 1955. None of the correlation coefficients are significant for employees who were in grade 14 on January 1, 1955.

Correlation Between Promotions and Publications by Grade of Scientist and by Degree Held

Scientists were separated by degree held on January 1, 1955 as well as by grade on January 1, 1955 to determine correlation coefficients between number of promotions and publications. The results are shown in table 34. They are essentially the same as those shown in table 33, where scientists were grouped by grade on January 1, 1955 without regard to degree held. Correlation coefficients between promotions and publications are highly significant for scientists in grades 5 through 12 on January 1, 1955.

Correlation Between Promotions and Publications by Grade and by Number of Years a Scientist Had Published

The correlation coefficients between publications and promotions when scientists were separated by length of experience as well as by grade on January 1, 1955, as shown in table 35, are in essential

TABLE 34.—*Correlation coefficients between number of grade changes from Jan. 1, 1955, to Jan. 1, 1965, and 4 publication measures, by grade of scientist and degree held on Jan. 1, 1955* [1]

Publication measure and degree on Jan. 1, 1955	Grade, Jan. 1, 1955						
	5	7	9	11	12	13	14
Publications per year							
Jan. 1, 1955, to Jan. 1, 1965:							
Doctor's	---	---	**0.464	**0.381	**0.378	*0.280	0.066
Master's	---	**0.441	**.397	**.379	.168	.264	---
Bachelor's	**0.595	**.430	**.227	**.446	*.383	---	---
To Jan. 1, 1965:							
Doctor's		---	**.519	**.328	**.290	*.257	.177
Master's	---	**.418	**.367	**.327	**.299	.169	---
Bachelor's	**.639	**.410	**.258	**.388	*.336	---	---
Publication score per year							
Jan. 1, 1955, to Jan. 1, 1965:							
Doctor's	---	---	**.384	**.439	**.365	.107	.306
Master's	---	**.442	**.398	**.425	.219	.446	---
Bachelor's	**.667	**.520	**.275	**.543	.269	---	---
To Jan. 1, 1965:							
Doctor's		---	**.443	**.383	**.359	.091	.384
Master's	---	**.439	**.400	**.417	**.319	**.412	---
Bachelor's	**.649	**.493	**.270	**.456	*.331	---	---

*Significant at the 5-percent level.
**Significant at the 1-percent level.

[1] Correlation coefficients not given where number of respondents in a group was less than 18.

TABLE 35.—*Correlation coefficients between number of grade changes from Jan. 1, 1955, to Jan. 1, 1965, and 4 publication measures, by grade Jan. 1, 1955 and number of years of publishing to Jan. 1, 1965* [1]

Publication measure and number of years of publishing	Grade, Jan. 1, 1955						
	5	7	9	11	12	13	14
Publications per year							
Jan. 1, 1955, to Jan. 1, 1965:							
31+	---	---	---	0.168	**0.283	**0.396	---
21 to 30	---	0.422	**0.363	**.364	**.363	.156	---
11 to 20	**0.647	**.475	**.362	**.462	.248	---	---
0 to 10	**.590	**.371	*.435	---	---	---	---
To Jan. 1, 1965:							
31+	---	---	---	.031	**.283	**.418	---
21 to 30	---	.342	.207	**.325	**.282	.111	---
11 to 20	**.712	**.473	**.390	**.427	*.305	---	---
0 to 10	**.561	*.279	**.598	---	---	---	---
Publication score per year							
Jan. 1, 1955, to Jan. 1, 1965:							
31+	---	---	---	.245	**.375	*.293	---
21 to 30	---	*.579	**.437	**.453	**.261	.115	---
11 to 20	**.656	**.527	**.367	**.488	*.332	---	---
0 to 10	**.691	.226	**.698	---	---	---	---
To Jan. 1, 1965:							
31+	---	---	---	.087	**.432	*.330	---
21 to 30	---	**.604	**.353	**.439	**.279	.037	---
11 to 20	**.658	**.524	**.390	**.450	*.389	---	---
0 to 10	**.646	.131	**.726	---	---	---	---

*Significant at 5-percent level.
**Significant at 1-percent level.

[1] Correlation coefficients not given where number of respondents in a group was less than 18.

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agreement with those obtained when the scientists were separated by grade only. The correlation coefficients between promotions and publications are highly significant for scientists in grades 5 through 12 on January 1, 1955. However, for those scientists in grade 11 on January 1, 1955 who had been publishing 21 or more years at that time (31+ to January 1, 1965), the correlation coefficients between publications and promotions were not significant. For those scientists in grades 12 and 13 with 21 or more years of publishing on January 1, 1955 (31+ to January 1, 1965) the correlation coefficients between publications and promotions were significant.

Net Change in Quality of ARS Scientists for Two Time Periods

In 1957, Dr. William Shockley introduced merit index as a tool for studying in an objective way the problem of quality losses in civil service laboratories (*7*). He defined merit index for an individual for a given date as the fraction of employees of his age that the individual exceeds in salary. Thus, the person having the top salary for his age will have an index of 1.0; the person having the median salary will have an index of 0.5; and the person having the lowest salary will have an index of 0. Dr. Shockley analyzed losses of scientists in terms of their distribution in various merit quartiles. He found in the National Bureau of Standards that the top quartile had approximately 50 percent more losses than its proper share. If these losses are not balanced by suitable recruiting into the top quartile, the quality of the scientists in the laboratory goes down.

The present study of quality changes in ARS modifies Shockley's method of analysis by assigning a quality value (called quality factor) to each 10 percentile of merit indexes as follows:

Merit index group	*Quality factor*
1. 0.9+ to 1.0	+5
2. 0.8+ to 0.9	+4
3. 0.7+ to 0.8	+3
4. 0.6+ to 0.7	+2
5. 0.5+ to 0.6	+1
6. 0.4+ to 0.5	−1
7. 0.3+ to 0.4	−2
8. 0.2+ to 0.3	−3
9. 0.1+ to 0.2	−4
10. 0.0 to 0.1	−5

If a scientist is lost from the first merit index group (0.9+ to 1.0) by reason of resignation, retirement, death, etc., the quality change is −5 (−1×5). If a scientist is recruited who falls in the first merit index group, the quality change is +5 (+1×5). If a scientist is lost from the 10th merit index group (0 to 0.1), the quality change is +5 (−1×−5). If a scientist is recruited who falls in the 10th merit index group, the quality change is −5 (+1×−5). The net change in quality of ARS scientists during a given period is calculated by summing the products of the net change in number of scientists in each merit index group by the quality factor in that group.

Merit indexes were calculated for all employees on the rolls on June 30, of 1956, 1960, and 1965. Those employees lost between June 30, 1956, and June 30, 1960, were tabulated by their merit index on June 30, 1956. Those employees hired between June 30, 1956, and June 30, 1960, were tabulated by their merit index on June 30, 1960. Similarly, those employees lost between June 30, 1960, and June 30, 1965, were tabulated by their merit index on June 30, 1960. Those employees hired between June 30, 1960, and June 30, 1965, were tabulated by their merit index on June 30, 1965.

The reason for using the time periods 1956 to 1960 and 1960 to 1965 was that ARS changed the method of classifying scientists to the "man in the job" concept in 1959. It was believed that the new classification procedure would help in both retention of good scientists and the recruitment of new scientists.

The net change in quality of ARS scientists by age groups and for all ARS from June 30, 1956, to June 30, 1960, is shown in table 36. There was a small net decrease in quality (−66) for all ARS scientists. This was made up by increases in quality for the age groups 24+ to 29 (+51), 29+ to 34 (+51), and 54+ to 59 (+7), and decreases in quality in all other age groups.

The net quality changes associated with losses in the period June 30, 1956, to June 30, 1960, and the net quality changes associated with new recruits

are shown in table 37. It is seen that quality decreases associated with losses occurred in only two age groups, whereas quality decreases associated with new recruits occurred in seven age groups.

The net change in quality of ARS scientists by age groups and for all ARS from June 30, 1960, to June 30, 1965, is shown in table 38. There was a small net increase in quality (+87) for all ARS scientists. This net increase is made up of a decrease in quality (−33) in the age group 44+ to 49 and net increases in quality for all other age groups.

TABLE 36.—*Net change in number of scientists from June 30, 1956, to June 30, 1960, by merit index group* [1] *and by age of scientist on June 30, 1960; also, net change in quality of scientists by age group and total ARS change in quality* [2]

Age group June 30, 1960	Net change in number of scientists, by merit index group and associated quality factors [3]										Net change in quality for age group [4]
	0.9+ to 1.0 (+5)	0.8+ to 0.9 (+4)	0.7+ to 0.8 (+3)	0.6+ to 0.7 (+2)	0.5+ to 0.6 (+1)	0.4+ to 0.5 (−1)	0.3+ to 0.4 (−2)	0.2+ to 0.3 (−3)	0.1+ to 0.2 (−4)	0 to 0.1 (−5)	
24+ to 29	15	14	9	10	16	9	5	11	9	11	51
29+ to 34	26	22	22	33	25	5	22	23	24	22	51
34+ to 39	14	10	9	24	17	17	12	15	14	16	−20
39+ to 44	4	4	7	5	7	0	12	11	5	16	−83
44+ to 49	−1	3	0	1	4	1	0	7	3	0	−21
49+ to 54	2	1	2	0	1	0	3	3	−3	4	−2
54+ to 59	3	−1	4	0	1	−2	−1	1	2	2	7
59+ to 64	−4	−1	1	−4	0	2	0	1	0	2	−44
64+ to 69	−2	0	0	−1	1	1	−2	0	−2	1	−5
Total	57	52	54	68	72	33	51	72	52	74	−66

[1] The merit index for an individual for a given date is the fraction of the employees of his age that the individual exceeds in salary. Thus, the person having the top salary for his age will have an index of 1.0; the person having the median salary will have an index of 0.5; and the person having the lowest salary will have an index of 0.

[2] 4 utilization research divisions not included because of lack of payroll data June 30, 1956.

[3] Associated quality factors are the figures in parentheses.

[4] Summation of products of number of scientists times quality factor for the 10 merit index groups in each age group.

TABLE 37.—*Number of scientists who resigned and number employed from June 30, 1956, to June 30, 1960 by age; also, quality changes resulting from losses and gains* [1]

Age group June 30, 1956	Number of scientists on rolls June 30, 1956	Number of scientists who resigned to June 30, 1960	Quality change resulting from resignations [2]	Age group June 30, 1960	Number of scientists on rolls June 30, 1960	Number of scientists employed since June 30, 1956	Quality change resulting from new employees	Net change in quality by age group on June 30, 1960
20+ to 25	12	5	9	19+ to 24	17	17	0	0
25+ to 30	80	21	0	24+ to 29	121	114	42	9+ 42= 51
30+ to 35	196	38	15	29+ to 34	303	245	51	0+ 51= 51
35+ to 40	237	25	28	34+ to 39	341	186	−35	15− 35=−20
40+ to 45	176	17	5	39+ to 44	307	96	−111	28−111=−83
45+ to 50	174	15	13	44+ to 49	191	35	−26	5− 26=−21
50+ to 55	187	11	10	49+ to 54	185	28	−15	13− 15= −2
55+ to 60	120	18	−18	54+ to 59	192	20	−3	10− 3= 7
60+ to 65	52	19	0	59+ to 64	116	15	−26	−18− 26=−44
65+ to 70	34	30	−3	64+ to 69	48	15	−5	0− 5= −5
Total	1,268	199	59		1,821	771	−128	−66

[1] 4 utilization research divisions not included because of lack of payroll data June 30, 1956.

[2] Resignations, death, retirement, etc.

It would appear that changing to the "man in the job" classification had the desired effects.

The net quality changes resulting from losses and from new recruits in the period June 30, 1960, to June 30, 1965, are shown in table 39. Quality decreases associated with losses occurred in three age groups. Quality decreases associated with new recruits occurred in five age groups. The decreases in quality associated with new recruits was less in the period June 30, 1960, to June 30, 1965, than it was from June 30, 1956 to June 30, 1960.

TABLE 38.—*Net change in number of scientists from June 30, 1960, to June 30, 1965, by merit index group [1] and by age of scientist on June 30, 1965; also, net change in quality of scientists by age group and total ARS change in quality*

Age group June 30, 1965	Net change in number of scientists, by merit index group and associated quality factors [2]										Net change in quality for age group [3]
	0.9+ to 1.0 (+5)	0.8+ to 0.9 (+4)	0.7+ to 0.8 (+3)	0.6+ to 0.7 (+2)	0.5+ to 0.6 (+1)	0.4+ to 0.5 (−1)	0.3+ to 0.4 (−2)	0.2+ to 0.3 (−3)	0.1+ to 0.2 (−4)	0 to 0.1 (−5)	
24+ to 29	17	22	23	12	10	19	17	18	19	17	8
29+ to 34	36	34	8	31	8	23	34	20	29	28	3
34+ to 39	14	18	14	12	17	22	9	17	10	16	14
39+ to 44	5	17	3	9	−5	11	2	7	0	15	4
44+ to 49	−4	4	3	3	3	9	1	−1	6	3	−33
49+ to 54	6	7	5	−1	3	2	1	5	6	2	21
54+ to 59	1	1	3	−5	0	0	0	0	−1	−2	22
59+ to 64	3	−2	−4	0	−4	−2	0	−3	−1	−6	36
64+ to 69	−2	−5	−4	−5	−5	−6	−5	−2	−8	−3	12
Total	76	96	51	56	27	78	59	61	60	70	87

[1] See table 36, footnote 1.

[2] Associated quality factors are the figures in parentheses.

[3] Summation of products of number of scientists times quality factor for the 10 merit index groups in each age group.

TABLE 39.—*Number of scientists who resigned and number employed from June 30, 1960, to June 30, 1965, by age; also, quality changes resulting from losses and gains*

Age group June 30, 1960	Number of scientists on rolls June 30, 1960	Number of scientists who resigned to June 30, 1965	Quality change resulting from resignations [1]	Age group June 30, 1965	Number of scientists on rolls June 30, 1965	Number of scientists employed since June 30, 1960 [2]	Quality change resulting from new employees	Net change in quality by age group on June 30, 1965
19+ to 24	32	8	−35	19+ to 24	14	14	0	0
24+ to 29	182	33	−64	24+ to 29	205	182	43	−35+43= 8
29+ to 34	402	71	35	29+ to 34	433	284	67	−64+67= 3
34+ to 39	488	84	39	34+ to 39	551	220	−21	35−21=14
39+ to 44	442	51	56	39+ to 44	551	148	−35	39−35= 4
44+ to 49	310	20	43	44+ to 49	469	78	−89	56−89=−33
49+ to 54	264	23	11	49+ to 54	346	56	−22	43−22=21
54+ to 59	241	43	28	54+ to 59	261	20	11	11+11=22
59+ to 64	149	59	30	59+ to 64	222	24	8	28+ 8=36
64+ to 69	66	60	−1	64+ to 69	104	14	−18	30−18=12
Total	2, 576	452	142		3, 156	1, 040	−56	87

[1] Resignations, death, retirement, etc.

[2] Includes employees transferred to ARS in 2 marketing divisions.

Merit Index of Scientists June 30, 1956, Who Were Research Supervisors June 30, 1965

It is sometimes stated that research supervisors in Government laboratories get their positions by default. In other words, it is contended that the more able employees leave Government service and employees of lesser ability thereby get the promotions to positions which should have been filled by people of more ability. It seemed desirable to test this hypothesis in ARS. The results of the analysis are shown in table 40.

For those scientists who have been continuously employed by ARS since January 1, 1955, who were research supervisors on June 30, 1965, the mean merit index by position title on June 30, 1965, was calculated for June 30, 1956. It was found that all means were above the median merit index for scientists of the same age. It thus appears that ARS does a reasonable job of selecting research supervisors from above-average employees and that promotions to these positions were not by default. This is particularly so for laboratory chiefs and division directors whose mean merit index 9 years before June 30, 1965, was above 0.8.

TABLE 40.—*Merit index of scientists June 30, 1956, who were research supervisors on June 30, 1965, by position title June 30, 1965*

Position title June 30, 1965	Number of respondents [1]	Mean merit index June 30, 1956
Investigations leader	147	0.691
Laboratory director	18	.690
Field station superintendent	29	.524
Laboratory chief	17	.824
Branch chief [2]	53	.746
Division director [2]	21	.916

[1] Only those employed continuously by ARS since Jan. 1, 1955.
[2] All employees in office of chief and director.

The Relation Between Merit Index and Publication Records

Correlation coefficients between merit index and three publication measures by age of scientists are given in table 41. There is a very highly significant correlation between merit index and number of publications, and an even higher correlation between merit index and publication scores. In 32 out of 46 comparisons publication score was more highly correlated with merit index than the number of publications was. This shows that quality of publications as well as quantity of publications is considered by personnel evaluation committees in classifying scientists.

There was a much lower correlation between merit index and the highest rank order assigned by scientists to any of their publications than for the other two publication measures. Even so, in all but two age groups merit index was correlated positively with highest rank order. In 18 out of 46 age groups the correlation between merit index and highest rank order was significant at the 1-percent level.

In table 42 the mean number of publications is given by age of scientist and by merit index. With a few exceptions, there is a gradual decrease in the mean number of publications going from the top merit index group to the bottom index group for each of the age groupings. Also, with few exceptions there is an increase in the mean number of publications with age in each merit index group.

The mean publication score of scientists by age of scientist and merit index is given in table 43. Here again, with few exceptions the mean publication score decreases with decreases in merit index and increases with increases in age. It appears that scientists over 64 years of age may have been more conservative in scoring their publications than younger scientists.

The mean number of publications and the mean publication score for all ARS scientists by merit index are given in table 44. Those scientists in the top 10 percentile of salary for their age produced six times as many publications and had publication scores eight times those of scientists in the bottom 10 percentile of salary for their age.

The regularity of the increase in productivity with increase in salary for age is shown in figure 5. All means except those for the lowest merit index group lie in a straight line on a logarithmic scale. The scientists in the lowest 10 percentile of salary for their age are not producing as much as

they should to be consistent with the other merit index groups. It is apparent that ARS pays its scientists in accordance with their productivity. Also, for scientists of the same age, ARS gets more for its money from those currently in the highest levels of salary, because the spread in productivity is much wider than the spread in salary.

TABLE 41.—*Correlation coefficients between merit index June 30, 1965* [1] *and number of publications, publication score, and highest rank order on a single publication by age*

Age, June 30, 1965	Number of publications		Publication score		Highest rank order	
	Number of scientists	r [2]	Number of scientists	r [2]	Number of scientists	r [2]
24	16	0.412	14	0.395	2	0
25	20	*.547	14	*.553	4	.630
26	33	**.444	29	*.386	11	−.182
27	49	.201	46	**.385	16	**.644
28	57	.193	49	.259	35	.193
29	63	**.481	58	**.640	40	**.595
30	82	**.358	73	**.599	52	.216
31	61	**.418	50	**.547	41	.142
32	88	**.493	73	**.660	62	.243
33	106	**.394	90	**.513	88	**.318
34	113	**.617	101	**.722	85	**.404
35	88	**.575	77	**.548	73	**.439
36	119	**.530	104	**.680	102	**.318
37	95	**.491	88	**.601	83	**.363
38	112	**.493	99	**.677	98	**.369
39	97	**.566	84	**.643	85	**.422
40	109	**.362	97	**.561	98	.191
41	100	**.482	93	**.516	95	.081
42	102	**.516	93	**.673	91	**.455
43	124	**.418	113	**.523	115	.137
44	136	**.531	126	**.584	123	.091
45	99	**.657	93	**.674	91	**.458
46	79	**.565	74	**.593	74	.162
47	82	**.599	77	**.524	75	**.502
48	70	**.618	59	**.646	64	**.338
49	74	**.656	70	**.551	70	*.266
50	76	**.617	72	**.587	71	.225
51	83	**.613	75	**.637	73	**.467
52	58	**.665	57	**.651	53	*.319
53	52	**.463	47	**.466	49	.191
54	48	**.683	44	**.708	44	.250
55	57	**.462	54	**.579	54	**.429
56	50	**.517	46	**.589	46	*.350
57	54	**.666	52	**.644	52	*.288
58	46	**.620	44	**.576	43	.235
59	61	**.493	60	**.523	52	**.403
60	54	**.677	50	**.579	52	**.478
61	42	**.647	42	**.491	40	.149
62	31	**.497	31	*.413	30	*.362
63	28	**.588	27	**.520	27	.221
64	29	*.438	25	**.572	27	.175
65	24	*.514	22	**.590	23	*.444
66	19	**.680	17	**.734	15	**.695
67	22	.310	22	.383	20	.230
68	8	.344	8	−.202	8	−.534
69	6	.561	4	.569	6	.396

*Significant at 5-percent level.
**Significant at 1-percent level.

[1] See table 36, footnote 1.
[2] Correlation coefficient.

TABLE 42.—*Mean number of publications to Jan. 1, 1965, by age of scientists and by merit index* [1]

Age group June 30, 1965	Mean number of publications by merit index group, June 30, 1965									
	0.9+ to 1.0	0.8+ to 0.9	0.7+ to 0.8	0.6+ to 0.7	0.5+ to 0.6	0.4+ to 0.5	0.3+ to 0.4	0.2+ to 0.3	0.1+ to 0.2	0 to 0.1
24 to 28	3. 67	3. 47	4. 86	2. 39	1. 81	1. 40	1. 16	0. 79	0. 93	0. 33
29 to 33	11. 71	8. 75	6. 45	5. 70	4. 27	5. 23	4. 25	4. 31	2. 24	1. 42
34 to 38	22. 24	16. 44	11. 69	7. 99	7. 93	8. 00	8. 73	5. 48	5. 59	2. 28
39 to 43	31. 35	22. 11	19. 87	17. 43	16. 91	15. 33	10. 95	10. 73	13. 32	5. 30
44 to 48	44. 72	31. 91	32. 73	28. 57	20. 30	19. 36	16. 21	14. 24	10. 29	6. 30
49 to 53	55. 56	49. 05	41. 94	39. 60	30. 95	22. 56	17. 41	20. 24	15. 89	8. 12
54 to 58	78. 59	54. 42	49. 72	43. 67	36. 80	43. 27	33. 46	24. 50	16. 42	9. 38
59 to 63	78. 72	62. 80	58. 56	47. 16	54. 77	34. 76	31. 81	23. 61	20. 42	19. 47
64 to 68	87. 61	81. 41	53. 27	44. 01	63. 04	33. 04	38. 53	53. 36	33. 40	16. 00

[1] See table 36, footnote 1.

TABLE 43.—*Mean publication score to Jan. 1, 1965, by age of scientists and by merit index group, June 30, 1965* [1]

Age group June 30, 1965	Mean publication score by merit index group, June 30, 1965									
	0.9+ to 1.0	0.8+ to 0.9	0.7+ to 0.8	0.6+ to 0.7	0.5+ to 0.6	0.4+ to 0.5	0.3+ to 0.4	0.2+ to 0.3	0.1+ to 0.2	0 to 0.1
24 to 28	109	48	58	23	23	23	18	11	17	5
29 to 33	188	159	107	104	72	64	53	50	26	18
34 to 38	458	290	228	139	180	156	115	91	63	35
39 to 43	606	433	323	330	309	262	204	144	205	92
44 to 48	883	559	663	534	367	365	347	232	156	85
49 to 53	971	902	895	666	508	413	352	394	287	77
54 to 58	1, 562	1, 357	911	756	862	534	539	447	291	119
59 to 63	1, 313	1, 550	1, 112	1, 013	1, 065	714	589	523	405	337
64 to 68	1, 547	1, 130	796	776	825	770	804	542	521	315

[1] See table 36, footnote 1.

TABLE 44.—*Number of ARS scientists, mean number of publications, and mean publication score by merit index group, June 30, 1965* [1]

Item	Merit index group, June 30, 1965										Total
	0.9+ to 1.0	0.8+ to 0.9	0.7+ to 0.8	0.6+ to 0.7	0.5+ to 0.6	0.4+ to 0.5	0.3+ to 0.4	0.2+ to 0.3	0.1+ to 0.2	0 to 0.1	
Number of scientists, age 22 to 69	402	374	279	332	246	358	271	294	292	307	3, 155
Mean number of publications	39. 7	29. 8	28. 1	23. 7	20. 3	17. 7	14. 9	13. 3	11. 3	6. 2	20. 5
Mean publication score	757	607	541	446	392	314	276	222	183	94	382

[1] See table 36, footnote 1.

Recalculation of the Net Change in Quality of ARS Scientists in Two Time Periods

In tables 36 and 38, the net change in quality of ARS scientists was calculated using arbitrary quality factors from +5 to −5 for 10 merit index groups. In table 44 are shown actual mean publication scores for each merit index group. It was decided to recalculate net quality changes in ARS scientists using actual publication scores as the measure of quality factor for each merit index group. The quality factor was calculated as follows:

$$\frac{\text{Mean publication score of merit index group} - \text{ARS mean publication score}}{100}$$

or for merit index group 0.9+ to 1.0:

$$\frac{757-382}{100}=3.75$$

The results of the recalculation of net quality changes using real quality factors are shown in table 45. It can be seen that the same conclusions are reached using real quality factors as were reached using the arbitrary quality factors of +5 to −5 for the various merit index groups. It can now be stated with confidence that there was a small net decrease in quality of ARS scientists in the period June 30, 1956, to June 30, 1960, and a small net increase in quality in the period June 30, 1960, to June 30, 1965.

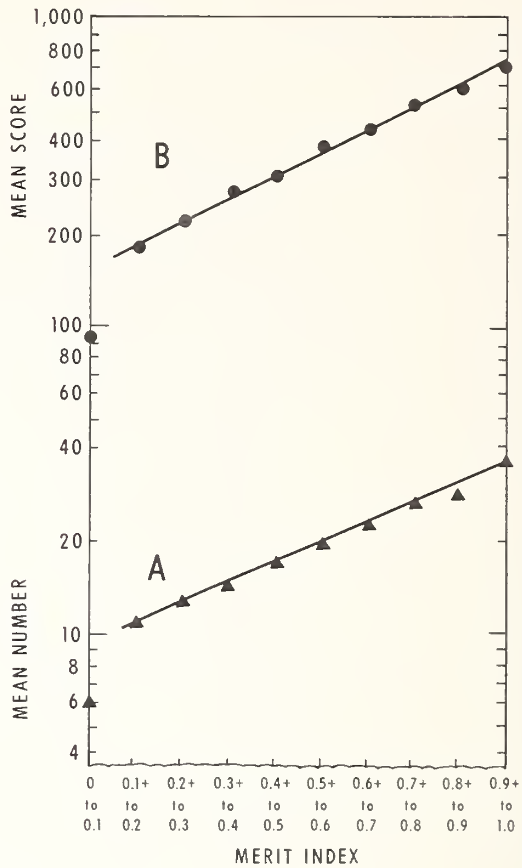

FIGURE 5.—Relationship between merit index and (A) mean number of publications and (B) mean publication score.

TABLE 45.—*Net change in number of scientists in 2 periods by merit index group* [1] *and net change in quality of scientists in the same 2 periods*

Period	Net change in number of scientists, by merit index group and associated quality factors [2]										Net change in quality of ARS scientists [3]
	0.9+ to 1.0 (3.75)	0.8+ to 0.9 (2.25)	0.7+ to 0.8 (1.59)	0.6+ to 0.7 (0.64)	0.5+ to 0.6 (0.10)	0.4+ to 0.5 (−0.68)	0.3+ to 0.4 (−1.06)	0.2+ to 0.3 (−1.60)	0.1+ to 0.2 (−1.99)	0 to 0.1 (−2.88)	
June 30, 1956, to June 30, 1960	57	52	54	68	72	33	51	72	52	74	−40.97
June 30, 1960, to June 30, 1965	76	96	51	56	27	78	59	61	60	70	86.45

[1] See table 36, footnote 1.

[2] Quality factors (figures in parentheses) were determined from the mean publication scores for each merit index group as follows:

$$\frac{\text{Mean publication score of merit index group} - \text{ARS mean publication score}}{100}$$

[3] Summation of the products of number of scientists times the quality factor for the 10 merit index groups.

Correlation Between Merit Index and Publications for Two Time Periods

Correlation coefficients were calculated between merit index June 30, 1956, and (1) publications per year to January 1, 1955, and (2) publication score per year to January 1, 1955. Also, correlation coefficients were calculated between merit index June 30, 1965, and (1) publications per year to January 1, 1965, and (2) publication score per year to January 1, 1965. The results are shown in table 46. The correlation coefficients were highly significant in both time periods. Merit index was more highly correlated with publication score per year than with publications per year. Both publication measures were more highly correlated with merit index in the latter time period than in the earlier one.

TABLE 46.—*Correlation coefficients between merit index and 2 publication measures for 2 periods of time for the 1,327 scientists employed continuously by ARS since Jan. 1, 1955*

Measures compared	Correlation coefficient
Merit index June 30, 1956, and publications per year to Jan. 1, 1955	**0. 339
Merit index June 30, 1956, and publication score per year to Jan. 1, 1955	**. 389
Merit index June 30, 1965, and publications per year to Jan. 1, 1965	**. 497
Merit index June 30, 1965, and publication score per year to Jan. 1, 1965	**. 542

**Significant at 1-percent level.

Peer Evaluation of Research Publications Compared With a Scientist's Own Evaluation of His Publications

Publications of 89 scientists selected at random were evaluated by peer groups. The peer groups were composed of the members of 10 Division Personnel Evaluation Committees. Each committee evaluated publications of up to 11 scientists in its own division. The members of each committee are senior scientists representing the disciplines within a division. Thus, in the Crops Research Division one would likely find geneticists, physiologists, pathologists, horticulturists, and agronomists on the Division Personnel Evaluation Committee. In a strict sense this does not represent a peer group for the review of publications in genetics or any other single discipline in the Crops Research Division. A strict definition of a peer group would require that all peers evaluating genetics publications be geneticists, and that peers evaluating pathology publications be pathologists.

The situation described in the Crops Research Division is the most diverse of all the divisions. In three other divisions where peer ratings were made, the discipline diversity approaches that of Crops. In six divisions the disciplines are more closely related. Nevertheless, it was decided that, since these committees constitute the mechanism by which scientists are currently evaluated, the members of these committees could be called peers for the purposes of this study. Since each member of a committee was asked to evaluate independently the publications of the selected scientists, it was expected that the ratings given a scientist by four to seven raters would have a wider variation than would likely be the case with a strict peer group.

Of the 89 sets of publications rated by peers, only 36 could be compared with the scientist's own evaluation. The reason for this was that the peers and the scientist rated a different number of publications in the other 53 cases.

Results from the 36 scientists who rated the same number of publications as were rated by peers are shown in table 47. In 13 cases the scientist's own publication score fell within the range of peer scores. In four of these the scientist's own score was lower than the mean peer score. In an additional six cases the scientist's own publication score did not exceed the highest peer score by more than 10 percent. Thus, in 19 out of 36 cases the scientist's own evaluation of his publications and peer evaluations were reasonably related. In the other 17 cases personal evaluations were higher than peer evaluations. However, in only 5 of the 36

cases did the ratio of personal score to mean peer score exceed 2. In 12 of the 36 cases the ratio of highest peer score to lowest peer score exceeded 2.

The 53 cases rated by peers that were not comparable with personal evaluations are shown in table 48. The range in peer scores is much wider than one would desire in many cases. However, in the column, "Peer mean score per paper," it is evident that differences between scientists were shown. In order to see if there was a relationship between the diversity of disciplines represented in a division and the range in individual peer ratings, table 49 was prepared. In this table, the scientists listed in both tables 47 and 48 are arranged by the peer groups that evaluated their publications so as to show any differences between peer groups. (Differences could result from the diversity of disciplines represented by the scientists in a division as well as by the diversity of disciplines represented by the peer group.) The last column in table 49, giving ratio of highest score to lowest score, shows the diversity in peer ratings.

TABLE 47.—*Peer evaluation of research publications and scientist's evaluation of his own publications*

Scientist	Number of papers	Peer mean credit	Personal credit	Peer mean score	Personal score	Range in scores among peers
1	49	20.8	22.0	618.6	[1] 496.0	473.0–779.0
2	19	8.6	8.75	245.4	[2] 308.0	186.0–294.0
3	11	2.6	2.7	51.5	113.0	21.5– 81.0
4	8	3.8	3.8	64.8	[1] 57.0	55.5– 76.0
5	2	1.9	2.0	33.3	50.0	30.0– 40.0
6	2	1.3	1.1	32.0	[2] 44.4	19.0– 42.0
7	12	7.6	7.6	163.8	236.0	158.5–164.0
8	13	3.0	3.1	86.2	[1] 94.0	60.0–124.6
9	1	.6	1.0	30.4	[1] 36.0	15.0– 42.0
10	4	2.2	3.2	63.7	[1] 35.0	31.0–110.0
11	14	5.9	5.8	172.0	346.0	102.0–282.0
12	9	6.8	7.3	143.4	[2] 264.0	93.0–258.0
13	24	16.9	17.1	298.3	900.0	196.0–480.0
14	9	7.8	8.1	115.1	301.0	54.0–180.0
15	25	11.7	11.9	245.3	[1] 310.0	142.0–363.0
16	15	9.0	10.3	215.8	394.0	145.0–275.0
17	16	9.1	8.9	331.0	[1] 500.0	261.0–500.0
18	2	1.8	1.6	15.0	29.0	15.0– 15.0
19	4	2.0	2.0	42.3	105.0	33.0– 50.0
20	3	2.3	2.9	47.7	95.0	34.0– 65.0
21	3	2.0	2.0	68.0	[1] 87.0	57.0– 90.0
22	8	4.1	5.4	160.5	276.0	156.0–165.0
23	8	3.3	3.4	98.5	[2] 139.6	74.0–136.0
24	15	4.5	5.1	162.5	615.0	108.0–215.0
25	36	10.5	10.0	355.8	[1] 376.5	262.0–430.0
26	9	4.2	4.4	145.4	259.5	103.0–177.5
27	11	4.7	4.6	166.8	250.0	144.1–205.0
28	9	3.1	4.8	165.0	[1] 190.0	95.0–235.0
29	4	1.7	1.7	66.5	[1] 65.0	54.0– 79.0
30	9	3.7	3.6	206.3	[1] 222.0	169.0–229.0
31	6	4.7	5.8	277.0	[1] 355.0	209.0–360.0
32	11	5.0	6.8	210.0	360.0	159.0–253.0
33	30	11.9	14.0	513.0	[2] 615.0	455.0–608.0
34	15	3.6	3.9	138.0	219.0	115.0–157.0
35	21	7.7	8.0	186.5	[2] 236.0	107.0–220.0
36	11	3.0	3.0	98.8	142.5	92.0–112.0

[1] Personal score within peer range.
[2] Personal score outside the peer range but does not exceed the highest peer score by more than 10 percent.

TABLE 48.—*Range in publication scores and mean publication scores of peers for scientists whose personal evaluation could not be compared with peer evaluations*

Scientist	Number of papers	Peer mean score	Range in peer scores	Peer mean score per paper	Scientist	Number of papers	Peer mean score	Range in peer scores	Peer mean score per paper
1	16	255	208–302	15.9	28	1	15	12– 20	15.0
2	15	163	151–174	10.8	29	1	21	10– 28	21.0
3	7	104	95–112	14.9					
4	10	114	105–122	11.4	30	18	259	186–366	14.4
5	9	124	107–167	13.8	31	3	43	26– 82	14.3
6	20	270	247–321	13.5	32	10	153	90–231	15.5
7	5	87	57–117	17.4	33	15	293	183–448	19.5
8	5	127	94–168	25.4	34	15	278	171–347	18.5
9	2	71	52– 96	35.5	35	9	108	57–166	12.0
					36	9	82	40–134	9.1
10	16	323	247–382	20.2	37	11	119	69–183	10.8
11	6	102	48–154	17.0	38	8	152	120–183	19.0
12	14	248	192–326	17.7	39	13	114	61–192	8.8
13	6	188	98–270	31.3					
14	20	196	157–236	9.8	40	6	123	73–196	20.5
15	10	195	160–214	19.5	41	16	176	125–288	11.0
16	6	77	60–107	12.8	42	9	118	73–189	13.1
17	29	277	202–331	9.6	43	18	236	136–408	13.1
18	11	145	117–166	13.2	44	8	84	35–185	10.5
19	13	195	175–236	15.0	45	15	140	63–249	9.3
					46	13	118	62–192	9.1
20	18	400	283–548	22.2	47	3	48	17– 80	16.0
21	15	144	116–166	9.6	48	11	113	56–260	10.3
22	15	305	245–360	20.3	49	13	185	156–224	14.2
23	11	131	101–163	11.9					
24	22	268	227–296	12.2	50	11	161	149–180	14.6
25	11	52	39– 70	4.7	51	7	140	108–180	20.0
26	19	107	65–175	5.6	52	16	375	325–428	23.4
27	15	116	61–165	7.7	53	4	71	52– 93	17.8

TABLE 49.—*Range of peer scores on the publications of individual scientists by peer group*

Peer group [1] and scientist	Number of papers	Range in scores among peers	Ratio of highest peer score to lowest peer score	Peer group [1] and scientist	Number of papers	Range in scores among peers	Ratio of highest peer score to lowest peer score
Group 1 (91, 96):				Group 2 (77, 93):			
1	49	473–779	1.65	11	15	145–275	1.90
2	19	186–294	1.58	12	16	261–500	1.92
3	29	202–331	1.64	13	2	15– 15	1.00
4	11	117–166	1.42	14	4	33– 50	1.52
5	13	175–236	1.35	15	3	34– 65	1.91
6	18	283–548	1.94	16	3	57– 90	1.58
7	15	116–166	1.43	17	3	17– 80	4.71
8	15	245–360	1.47	18	11	56–260	4.64
9	11	101–163	1.61				
10	22	227–296	1.30				

See footnote at end of table.

TABLE 49.—*Range of peer scores on the publications of individual scientists by peer group*—Continued

Peer group [1] and scientist	Number of papers	Range in scores among peers	Ratio of highest peer score to lowest peer score	Peer group [1] and scientist	Number of papers	Range in scores among peers	Ratio of highest peer score to lowest peer score
Group 3 (78, 89):				Group 7 (45, 83):			
19	11	144–205	1. 42	55	14	102–282	2. 76
20	9	95–235	2. 47	56	9	93–258	2. 77
21	4	54– 79	1. 46	57	24	196–480	2. 45
22	13	156–224	1. 44	58	10	90–231	2. 57
23	11	149–180	1. 21	59	15	183–448	2. 45
24	7	108–180	1. 67	60	15	171–347	2. 03
25	16	325–428	1. 32	61	9	57–166	2. 91
26	4	52– 93	1. 79	62	9	40–134	3. 35
				63	11	69–183	2. 65
Group 4 (71, 95):				64	8	120–183	1. 53
27	11	159–253	1. 59				
28	30	455–608	1. 34	Group 8 (45, 74):			
29	15	115–157	1. 37	65	11	22– 81	3. 77
30	21	107–220	2. 06	66	8	56– 76	1. 37
31	11	92–112	1. 22	67	2	30– 40	1. 33
32	20	157–236	1. 50	68	2	19– 42	2. 21
33	10	160–214	1. 34	69	12	159–164	1. 03
34	6	60–107	1. 78	70	11	39– 70	1. 79
				71	19	65–175	2. 69
Group 5 (76, 87):							
35	9	169–229	1. 36				
36	6	209–360	1. 73	Group 9 (47, 71):			
37	5	57–117	2. 05	72	13	60–125	2. 08
38	5	94–168	1. 79	73	1	15– 42	2. 80
39	2	52– 96	1. 85	74	4	31–110	3. 55
40	16	247–382	1. 55	75	15	61–165	2. 70
41	6	48–154	3. 21	76	1	12– 20	1. 67
42	14	192–326	1. 70	77	1	10– 28	2. 80
43	6	98–270	2. 76	78	18	186–366	1. 97
				79	3	26– 82	3. 15
Group 6 (68, 82):							
44	15	108–215	1. 99	Group 10 (28, 60):			
45	36	262–430	1. 64	80	9	54–180	3. 33
46	9	103–178	1. 72	81	25	142–363	2. 56
47	16	208–302	1. 45	82	13	61–192	3. 15
48	15	151–174	1. 15	83	6	73–196	2. 68
49	7	95–112	1. 18	84	16	125–288	2. 30
50	10	105–122	1. 16	85	9	73–189	2. 59
51	9	107–167	1. 56	86	18	136–408	3. 00
52	20	247–321	1. 30	87	8	35–185	5. 29
53	8	156–165	1. 06	88	15	63–249	3. 95
54	8	74–136	1. 84	89	13	62–192	3. 10

[1] The first number in parentheses shows the percentage of scientists in a division in 1 discipline; the second figure in parentheses shows the percentage of scientists in 3 disciplines.

As might have been expected, the ratios between highest and lowest scores of peers on an individual scientist's publications were lower in those divisions having a narrower range of disciplines. In the first 6 divisions shown in table 49, the publications of 54 scientists were rated. In 23 cases the ratio between highest and lowest peer score was 1.50 or under. In 47 cases the ratio was under 2.00, and in only 7 cases was the ratio over 2.00. In contrast, in the last four divisions shown in table 49 where disciplines represented in a division are more diverse, the ratings of individual peers vary widely. In these last 4 divisions, the publications of 35 scientists were rated. In only three cases were the ratios between the highest and lowest peer score under 1.50, and in only seven cases were the ratios under 2.00. In 28 cases the ratios were over 2.00.

Even though the different peers in a group vary widely in the actual publication scores they give to the publications of one scientist, it may be that if 10 scientists' publications are evaluated, the differ-

ent peers would place scientists in the same rank order. In order to test this hypothesis, it is necessary to calculate for each peer the publication score per year given each scientist. Then, using his publication scores per year, rank the scientists from 1 to 10. This ranking can be compared with the rankings given by other peers in the same group for the same 10 scientists.

In order to compare the consistency of peer groups in ranking scientists, a consistency index has been formulated. The consistency index is calculated as follows:

(a) If 2 or more peers give a scientist the same rank order among 10 scientists, score 10 points each for the highest number of peers giving the same rank order. For the other peers, score nine points if their ranking is one rank order away from the rank order given by the highest number of peers, eight if two rank orders away, seven if three, six if four, five if five, four if six, three if seven, two if eight, and one if nine.

(b) If no 2 peers give a scientist the same rank order among 10 scientists, score the lowest ranking as 10, and for the others, score 9 if their ranking is 1 rank order away from the lowest ranking, 8 if 2, 7 if 3, 6 if 4, 5 if 5, 4 if 6, 3 if 7, 2 if 8, and 1 if 9.

Six peer groups had 5 or more peers evaluate the publications of 10 scientists. The evaluations of the first five peers in each of these six groups are shown in tables 50 to 55. The tables show the publication score per year given 10 scientists by each of 5 peers and the rank order given these same 10 scientists by the 5 peers based on the publication scores per year. The scientists are listed in the order of the average of the five separate rankings. The peer groups in tables 50 to 55 are designated by the same number as they are in table 49. The reason that a different number of scientists for a given peer group appears in table 49 is that in table 49 only those scientists who were rated on the same number of publications by all peers were considered. In tables 50 to 55, 10 scientists were considered. Where the number of publications differed among peers, the publication scores were adjusted to reflect the same number of papers.

It is evident from tables 50 to 55 that when 5 peers follow the same guidelines to independently evaluate the publications of 10 scientists, they are remarkably consistent in ranking the scientists. The consistency index could range from 20, where there would be no consistency in rankings, to 50, where there would be perfect agreement. All six peer groups had a consistency index above 45. Although peer groups 7, 8, and 10 had a wider range of scores among peers than peer groups 1, 2, and 6, all groups were equally consistent in placing scientists in the same rank order.

TABLE 50.—*Publication score per year and rank order given 10 scientists by 5 peers in peer group 1 and consistency index*

Scientist [1]	Publication score per year given by peer—					Rank order given by peer—					Rank order consistency index
	A	B	C	D	E	A	B	C	D	E	
1	61. 0	56. 5	66. 6	47. 3	77. 9	1	1	1	1	1	50
2	28. 3	42. 5	35. 3	38. 9	54. 8	3	2	4	2	2	47
3	25. 3	34. 1	41. 4	33. 9	38. 3	5	3	2	3	3	47
4	24. 5	31. 4	36. 0	32. 5	28. 4	6	4	3	4	6	45
5	34. 6	21. 9	31. 6	22. 8	33. 4	2	7	5	7	4	40
6	23. 2	27. 8	29. 6	30. 0	33. 2	7	6	6	5	5	47
7	25. 4	29. 5	22. 7	29. 6	26. 5	4	5	8	6	7	40
8	18. 3	17. 5	23. 6	19. 6	18. 7	8	8	7	8	8	49
9	11. 7	13. 6	15. 8	14. 9	16. 6	9	9	10	9	9	49
10	10. 1	12. 5	16. 3	13. 4	13. 3	10	10	9	10	10	49
Average for group 1											46. 3

[1] Scientists are listed in the order of the average of the 5 separate rank orders given by the peers.

TABLE 51.—*Publication score per year and rank order given 10 scientists by 5 peers in peer group 2 and consistency index*

Scientist [1]	Publication score per year given by peer—					Rank order given by peer—					Rank order consistency index
	A	B	C	D	E	A	B	C	D	E	
1	25. 6	36. 3	13. 8	26. 6	65. 4	1	1	1	1	1	50
2	14. 6	27. 5	11. 2	22. 7	46. 2	4	2	2	3	2	47
3	15. 1	23. 0	10. 7	17. 9	43. 8	3	3	3	4	3	49
3	15. 5	15. 8	10. 5	26. 5	39. 3	2	4	4	2	4	46
5	13. 3	7. 5	6. 5	14. 0	17. 9	5	8	5	5	7	45
5	8. 3	12. 5	6. 3	11. 0	23. 3	7	5	6	6	6	48
7	11. 8	7. 0	5. 6	8. 5	26. 0	6	9	7	7	5	45
8	5. 7	9. 0	3. 7	5. 7	10. 2	8	6	9	8	8	47
9	2. 7	8. 0	3. 3	3. 5	7. 5	10	7	10	9	9	46
10	3. 4	5. 0	4. 0	3. 4	6. 5	9	10	8	10	10	47
Average for group 2	------	------	------	------	------	------	------	------	------	------	47. 0

[1] Scientists are listed in the order of the average of the 5 separate rank orders given by the peers.

TABLE 52.—*Publication score per year and rank order given 10 scientists by 5 peers in peer group 6 and consistency index*

Scientist [1]	Publication score per year given by peer—					Rank order given by peer—					Rank order consistency index
	A	B	C	D	E	A	B	C	D	E	
1	64. 8	77. 7	34. 8	68. 0	61. 0	1	1	1	1	1	50
2	38. 6	34. 0	26. 2	43. 0	36. 4	2	2	2	2	2	50
3	26. 4	25. 6	16. 3	25. 2	32. 1	4	5	3	3	3	47
4	28. 1	30. 2	16. 1	20. 8	23. 6	3	3	4	5	4	47
5	20. 8	18. 4	15. 1	12. 9	22. 2	5	7	5	8	5	45
6	15. 4	30. 1	11. 8	18. 0	17. 1	8	4	7	6	7	45
7	17. 8	14. 0	10. 8	21. 5	19. 8	7	8	8	4	6	43
8	20. 4	20. 9	14. 0	14. 0	14. 2	6	6	6	7	9	46
9	13. 6	10. 9	7. 4	10. 8	14. 8	9	9	9	10	8	48
10	11. 2	9. 5	7. 4	11. 0	10. 3	10	10	9	9	10	48
Average for group 6	------	------	------	------	------	------	------	------	------	------	46. 9

[1] Scientists are listed in the order of the average of the 5 separate rank orders given by the peers.

TABLE 53.—*Publication score per year and rank order given 10 scientists by 5 peers in peer group 7 and consistency index*

Scientist [1]	Publication score per year given by peer—					Rank order given by peer—					Rank order consistency index
	A	B	C	D	E	A	B	C	D	E	
1	24. 7	32. 8	21. 1	44. 8	28. 6	4	2	1	1	2	46
2	26. 0	34. 6	17. 1	39. 0	25. 0	3	1	3	2	3	47
3	26. 8	29. 7	17. 1	32. 0	30. 3	2	3	3	4	1	46
4	48. 0	25. 8	19. 6	36. 0	20. 0	1	4	2	3	4	44
5	16. 6	20. 0	10. 2	28. 2	19. 0	5	5	5	5	5	50
6	12. 2	15. 9	9. 0	23. 1	16. 6	6	7	7	7	6	48
7	12. 0	15. 8	9. 7	25. 8	10. 9	7	8	6	6	7	47
8	9. 9	14. 6	6. 9	18. 3	10. 8	8	9	8	8	8	49
9	8. 0	16. 6	5. 7	16. 3	9. 9	9	6	9	9	9	47
10	6. 1	13. 4	5. 0	12. 4	4. 0	10	10	10	10	10	50
Average for group 7											47. 4

[1] Scientists are listed in the order of the average of the 5 separate rank orders given by the peers.

TABLE 54.—*Publication score per year and rank order given 10 scientists by 5 peers in peer group 8 and consistency index*

Scientist [1]	Publication score per year given by peer—					Rank order given by peer—					Rank order consistency index
	A	B	C	D	E	A	B	C	D	E	
1	28. 8	41. 5	34. 6	28. 0	9. 0	2	2	1	1	3	47
2	35. 0	45. 6	14. 0	23. 7	13. 0	1	1	5	2	1	45
3	23. 6	22. 8	26. 9	23. 6	10. 6	3	3	2	3	2	48
4	17. 8	20. 3	19. 9	19. 1	5. 9	4	4	3	4	5	48
5	9. 5	13. 9	16. 0	16. 9	7. 7	7	6	4	5	4	44
6	15. 2	15. 5	12. 6	11. 1	3. 8	5	5	6	7	6	47
7	8. 7	11. 6	5. 7	7. 7	3. 1	8	7	9	9	8	46
7	9. 7	9. 4	5. 4	12. 0	2. 0	6	9	10	6	10	41
9	7. 5	10. 0	7. 5	10. 0	2. 5	9	8	8	8	9	48
10	7. 1	3. 7	10. 3	6. 3	3. 4	10	10	7	10	7	44
Average for group 8											45. 8

[1] Scientists are listed in the order of the average of the 5 separate rank orders given by the peers.

TABLE 55.—*Publication score per year and rank order given 10 scientists by 5 peers in peer group 10 and consistency index*

Scientist [1]	Publication score per year given by peer—					Rank order given by peer—					Rank order consistency index
	A	B	C	D	E	A	B	C	D	E	
1	45. 3	136. 0	66. 3	50. 3	70. 7	1	1	1	1	1	50
2	24. 3	63. 0	27. 3	27. 3	35. 0	2	2	2	2	2	50
3	14. 2	32. 7	24. 2	19. 7	20. 1	3	3	3	3	3	50
4	13. 1	24. 1	14. 0	12. 5	13. 2	4	5	5	5	7	47
4	11. 7	25. 6	14. 1	13. 9	8. 9	5	4	4	4	9	44
6	10. 5	18. 9	10. 5	7. 6	14. 0	6	7	8	6	5	46
7	9. 3	17. 7	12. 6	6. 3	13. 3	7	8	7	8	6	47
8	9. 1	12. 9	10. 5	7. 3	14. 5	8	10	8	7	4	43
9	8. 3	14. 8	12. 8	5. 4	9. 8	10	9	6	10	8	43
10	8. 4	20. 6	5. 7	5. 6	3. 8	9	6	10	9	10	44
Average for group 10											46. 4

[1] Scientists are listed in the order of the average of the 5 separate rank orders given by the peers.

Some of the Problems Encountered in Evaluating Research Publications

Most scientists agree that research publications should be given significant weight in evaluations of scientists for promotion or placement actions. They further agree that quality of publications rather than quantity of publications should be the decisive factor in evaluating scientists. But I found no agreement among scientists on how quality can be measured or who should do the measuring. While scientists generally agree that the different authors on a paper with multiple authors deserve different amounts of credit, they see great difficulties with any system that apportions the credit.

Measuring Quality

One of the principal problems in measuring the quality of a publication is that opinions on quality change with time. Darwin's "Origin of Species" is given a much higher rating today than it was at the time of publication. The reverse is also frequently true. When first published, a given paper may appear to be of great interest, but later on it is shown to have missed the mark. For this reason, any scheme for measuring quality must provide for reevaluations periodically.

A second problem in measuring quality is that of assigning a number to a publication as a measure of its quality, as was done in the present study. The respondents to the questionnaire cooperated in this study on the assurance that the numbers would not be used in evaluations of themselves. Most scientists believe that they themselves or a group of peers can decide whether a paper is outstanding, average, or minor, but they feel that assigning one paper a rank order of 30 and another a rank order of 35 puts a cloak of too much objectivity on subjective judgment.

Because of the difficulties encountered in measuring quality, it was decided to explore how peers would rank the same scientists, first on the basis of publications per year and second on the basis of publication score per year, which includes quality along with numbers. The results are shown in table 56. There is reasonable agreement in the rankings. Out of the 60 scientists ranked, 16 were given the same ranking by both methods, 8 were ranked one-half order different, 14 were ranked 1 order different, 8 were ranked 1½ orders different, 8 were 2 orders different, 5 were 3 orders different, and 1 was 4 orders different.

The correlation coefficient between publications per year and publication score per year was found to be 0.71 for all scientists in the study in grades 11 through 15 on the basis of their own evaluations. It will also be recalled from earlier sections of this

TABLE 56.—*Ranking of 10 scientists by 6 peer groups by number of publications per year and by publication score per year given by peer groups*

Scientist	Rank order of scientists by peer group 1 based on—		Rank order of scientists by peer group 2 based on—		Rank order of scientists by peer group 6 based on—	
	Publications per year	Publication score per year	Publications per year	Publication score per year	Publications per year	Publication score per year
1	2	3	1	1	8	6
2	1	1	2.5	2	9	9
3	4	5	9	9	4	4
4	9.5	9	4	3.5	5	7
5	8	8	5.5	5.5	1.5	2
6	6	2	2.5	3.5	10	10
7	3	6	7	5.5	6.5	5
8	7	4	5.5	7	6.5	8
9	9.5	10	9	10	3	3
10	5	7	9	8	1.5	1

Scientist	Rank order of scientists by peer group 7 based on—		Rank order of scientists by peer group 8 based on—		Rank order of scientists by peer group 10 based on—	
	Publications per year	Publication score per year	Publications per year	Publication score per year	Publications per year	Publication score per year
1	4	5	6	7.5	5	6
2	9	7	5	6	10	8
3	7	6	10	9	6	4.5
4	2.5	1	3	5	2	2
5	2.5	3	9	7.5	1	1
6	9	9	7	4	8	9
7	9	10	8	10	3	3
8	1	4	2	2	9	10
9	6	8	4	3	7	7
10	5	2	1	1	4	4.5

report that the correlations of publication score per year with promotions and merit index were only slightly better than the correlations between publications per year and promotions and merit index. Thus, it would appear for ARS scientists, like the scientists studied by Dennis (*1*), that in general the scientists who produce the most publications are likely also to produce more papers of high quality. There are exceptions to this, of course, but Dennis found that among 19th century scientists who produced more than 140 papers, 70 percent were included in the Encyclopaedia Britannica as eminent scientists. Fifty percent of those who produced 50 or more papers were included. Of the remaining 187 scientists in Dennis' study who produced less than 50 publications, only 6 were included in the Encyclopaedia Britannica.

Since there is such a high correlation between quantity and quality, it would seem that a system which could divide publications into five classes on the basis of quality—outstanding, very important, important, average, and acceptable—would be adequate for purposes of evaluation.

Dividing Credit Among Multiple Authors

The guide used in the questionnaire to divide credit among authors brought forth several objections. Chief among these was that it would discourage teamwork in research. This is a valid objection. If an author knows that he will get a credit of one on a single-author paper and only 0.5 or 0.3 on a multiple-author paper, he is quite likely to favor doing research by himself. Another objection to the guide was that the first-named author is not always the principal contributor to the research. Many scientists try to encourage associates by placing the associate first among the authors even though the associate was not the principal contributor to the research. The reverse

is also true at times. Some supervisors take first place among authors even though a subordinate was the principal contributor. Also, some scientists add their supervisor to the author list as a courtesy.

Leaving aside these objections, dividing credit among authors could and probably would lead to serious morale problems. Some bitterness arises now in deciding the order in which authors are listed. If a higher proportion of credit were assigned to those first listed, this bitterness would increase manyfold.

Alternate schemes to the one used in the questionnaire have been examined, but none has proved to be satisfactory.

The correlation coefficient between publication credit per year and publication score per year was found to be 0.73 for all scientists in grades 11 through 15 on the basis of their own evaluations. Since this was almost identical to the correlation coefficient of 0.71 between publications per year and publication score per year, it is concluded that not much is gained by dividing credit among multiple authors. Scientists can be ranked as well by numbers of publications as they can by publication credit.

Who Should Measure the Quality of a Scientist's Research Publications for Promotion Purposes?

Most scientists agree that the scientist himself should not rate his own papers, but many feel that he should take part in the measuring process. Many believe that the immediate supervisor and others close to the work should do the rating. There is substantial belief that a paper should be rated by peers in the discipline represented by the paper. All these suggestions have merit, but in a large organization like ARS they also present many problems.

Consider rating by peers in the same discipline. If one scientist's papers are all rated by the same peers, it is likely that his papers will be ranked in proper relationship one to another. But, if another scientist's papers are rated by another set of peers, it is quite unlikely that the two scientists can be ranked in proper relationship to each other. To get a proper ranking of scientists, all papers in a given field, say plant genetics, would have to be rated by the same peers. This would place a heavy burden on the peers assigned to do the rating. But, even if such a scheme could be worked out, how could you compare scientists in plant genetics with scientists in plant physiology when the plant physiologists' publications would be rated by another set of peers?

Consider rating by the immediate supervisor and others close to the work. The supervisor is usually judged on the productivity of his unit. It would thus be to his advantage to give high ratings to the papers of his scientists. The same would be true for ratings by other scientists in the same group. Leaving this bias aside, it is quite unlikely that, with the large number of supervisors in ARS, the scientists in different groups would be placed in proper relationship to each other.

All things considered, it is concluded that the peer groups currently constituting the Division Personnel Evaluation Committees are in the best position to fairly evaluate the quality of publications of all scientists in a division. The present peers on these committees are all senior scientists familiar with their division's work and its scientists. They represent the various disciplines in a division and can thus make cross-discipline comparisons. They will not be biased to one discipline or one research group. Instead, they are in a position to evaluate a given publication in relation to the discipline represented by the publication and also in relation to the division's whole program.

As a matter of fact, the members of these committees are currently judging the quality of research publications. They do not put down a score for each publication or for all publications, but in arriving at a consensus of the merit of a given scientist, they do judge the quality and quantity of his publications along with other factors as they decide that scientist A ranks above scientist B.

If more formal recognition is to be given to the quality of individual publications, which I think would improve the evaluation process, the system of rating publications must be a simple one since the Division Personnel Evaluation Committees are already overworked. In the next section such a plan is suggested.

A Plan for Evaluating Research Publications

The plan proposed for measuring the quality of research publications adopts the quality definitions for degrees A, C, and E given in the U.S. Civil Service Commission Research Grade-Evaluation Guide, Factor IV: Qualifications and scientific contributions (*9*). Degrees B and D are a part of the plan but are undefined as in the guide. The plan assumes that the present Division Personnel Evaluation Committees will evaluate the quality of a scientist's publications in the normal course of their deliberations concerning promotion and placement.

Scientific publications are to be placed in one of five quality classes defined in reference to degrees A, B, C, D, and E, as follows.

A. Acceptable.—Fills narrow blanks in an existing framework of knowledge, or corroborates existing theory, or modifies known concepts and techniques to deal with a new situation, or establishes new concepts, techniques, or materials of limited interest, or restates or reviews previously published results with only minor additions to established knowledge.

B. Average.—Falls between classes A and C.

C. Important.—Establishes new concepts, techniques, or materials of considerable interest and value in a scientific field or solves a problem of considerable value to science or the public, or reviews, analyzes, and interprets scientific knowledge of broad scope.

D. Very Important.—Falls between classes C and E.

E. Outstanding.—Makes a major advance in a scientific field and opens the way for extensive further developments or solves a problem of great importance to science or the public.

A majority of all publications of all scientists, including the best scientists, will be expected to fall in classes A and B. For example, three of the top scientists in ARS rated their own papers as follows:

Class	Scientist		
	1	2	3
E. Outstanding	0	1	1
D. Very Important	2	1	3
C. Important	16	10	20
B. Average	40	36	30
A. Acceptable	13	93	66
Total papers	71	141	120

It is believed that peers would have given the publications of these scientists somewhat higher ratings than the scientists gave themselves.

The placement of a scientist's publications in the five quality classes is for one purpose only, to assist the committee in its evaluation of the scientist. No records of placement are to be kept. Since no records are kept, a reevaluation of the scientist's publications will be made the next time his case is before the committee. This will permit a change in judgment on a particular paper as time passes.

No standards can be set on how many papers in a given class would qualify a scientist to be placed in a given degree of Part IV of the Research Grade-Evaluation Guide (*9*) since publications are only one of the factors considered in placement. But ordinarily one would expect that scientists who are rated on total qualifications and achievements (publications, honors, awards, professional recognition, etc.) would have a publication pattern somewhat as follows:

Those given degree E would have one publication [3] on which they were a principal contributor in class E or alternatively two or more publications in class D. They would average one or more publications per year and have at least 10 publications in the combined classes C, D, and E.

Those given degree D would have one publication in class D or alternatively three or more pub-

[3] Wherever the word "publication(s)" is used, it should be interpreted as publications or patents, or both.

lications in class C. They would average one or more publications per year and would have at least 10 publications in the combined classes B, C, and D.

Those given degree C would have one or two publications in class C or alternatively four or more publications in class B. They would have at least six publications in the combined classes A, B, and C.

Those given degree B would have one to three publications in class B or alternatively five or more publications in class A.

Those given degree A would have from one to four publications in class A.

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Appendix

UNITED STATES DEPARTMENT OF AGRICULTURE
AGRICULTURAL RESEARCH SERVICE
WASHINGTON, D.C. 20250

OFFICE OF ADMINISTRATOR

August 16, 1965

To: Research Scientists and Research Supervisors in ARS

From: B. T. Shaw, Assistant to Administrator

Subject: Evaluation of Scientific Productivity

First of all, let me express my appreciation of the contributions you have made to agricultural research and of your efforts to make ARS an outstanding organization. I also want to thank you for the support given me during the years I was Administrator. I am sure you will give the same kind of support to Drs. Irving and Parker. These men are outstanding scientists and they have had much experience in research administration. They will work to advance agricultural science and to advance your interests as agricultural scientists.

From the comments I have had from many of you and from my own observations, it would appear that we might be able to work out more objective measures than we now have for evaluating research productivity. To this end, I am embarking on a study to "Develop more reliable criteria, methods and techniques for evaluating qualifications, achievements and professional stature of scientists in ARS." As I see it, different sets of values are involved in the following classes of positions:

(a) a research scientist
(b) a project leader
(c) an investigations leader
(d) a laboratory director
(e) a field station superintendent
(f) a laboratory chief
(g) a branch chief
(h) a division director

Also, different sets of values may well be required within a position class to evaluate adequately scientists engaged in different types of research. For example, it seems unlikely that the same rating factors would be equally valid for scientists doing beef cattle breeding research, scientists doing plant physiology research and scientists developing wholesale marketing facilities.

For a scientist working alone, rating factors should be based on his individual contributions. For a member of a team, rating factors should measure his contribution to and stimulation of team effort as well as

individual contributions. In rating an investigations leader, it seems to me that much greater weight should be given to the productivity of the investigations group than to his individual contributions. Branch chiefs and division directors need to be rated on economy of operations and other management factors as well as on the research output of their unit and their individual contributions. For all scientists, stature as a "leader" in a field of science or segment of agriculture or industry is an important rating factor.

Our division evaluation committees, composed of scientists and classification officers, do take into account the several bases for judgment that I have discussed above. I have been well pleased with the progress they have made in refining the "man in the job" concept of position classification. It is my hope that in the study I am undertaking I can develop some objective measures of output for different kinds of work and of professional standing that will assist our division evaluation committees to do an even better job. I intend to make a number of studies in depth on various rating factors, starting with the one that seems to be most troublesome.

The most frequent criticism I have had of our efforts so far is that the evaluation committees rely too heavily on publications and more particularly on a count of publications in making evaluations of scientists. I want to check the validity of this criticism and also ascertain, if possible, the situations in which publications (with appropriate attention to quality) can be given significant weight in grade determinations and the situations in which they cannot. I need your help to do this. I will need to divide ARS scientists into homogeneous groups and study the relation, if any, between publications (number and quality) and advancement. I shall also want to consider the relation, if any, between publications and your standing in ARS (as measured by salary and age) before and after the adoption of our current evaluation system. A questionnaire is attached with instructions for filling out that will provide the necessary information. But before you turn to the questionnaire, I want to discuss some of the guides I have set up for answering certain questions.

A. RANKING PUBLICATIONS

Quantity of publications presents no problems for measurement. The publications can be counted. Quality is an entirely different matter. It is doubtful that a single quantitative measure can be found that will adequately measure all facets of a research effort. Perhaps the best that can be done is to list a group of papers in rank order from the most to the least important. An individual scientist should be able to rank his own papers in this way. The problem becomes more difficult when the publications of several scientists are to be placed in one rank order. A few approaches to the solution of this problem have been suggested, for example:

1. Ranking by a peer group of scientists: (a) by reading all the papers; (b) by reading abstracts of the papers; or (c) by reading titles.

2. Ranking by the number of citations.

3. Ranking by the place of publication.

Most scientists, I believe, would accept suggestion 1(a) above but would have reservations on the others. For a small number of papers, it would be feasible to use a peer group to make the ranking after reading all papers. When the number of papers becomes large, as with the total list of publications of the 3480 scientists in ARS, this procedure has to be discarded. So also does suggestion 2 above. Rather than to use the method in suggestion 3 above, which has many obvious weaknesses, I believe a better result can be obtained by having each scientist place his papers in a single ARS rank order.

I recognize that ranking one's own efforts in relation to the efforts of all other ARS scientists presents opportunities for bias in both directions. Some of our people will be too modest and others may overrate their papers. But after allowing for this bias, I believe that with some guide lines and an effort on the part of all scientists to see their work as others see it, we can develop a better ranking of papers this way than by alternative methods.

I propose that we give top rank to original research followed by reviews of research for scientists and put reviews of research for laymen on the bottom end of the ranking. Let us visualize pigeonholes numbered from 1 to 100. We will reserve pigeonhole number 100 for the really outstanding contributions to science, such as Darwin's "Origin of Species," and place other papers in descending order down to pigeonhole number 1. So that we will all use the same frame of reference, I suggest the following guide to ranking:

<u>Rank Orders 100 to 81</u>: Original research having <u>very great impact</u> on science, agriculture or general welfare.

Papers falling in this range would be discussed in all histories of science pertaining to the given field. Also, the research would be cited in the writings of most, if not all, other scientists doing related research.

Note: I have examined the titles and the place of publication of the 3545 research publications coming out of ARS in calendar year 1964. With this background and with limited knowledge of the work, I estimate only two of the 3545 ARS 1964 publications will have <u>very great impact</u> on science, agriculture or general welfare.

<u>Rank Orders 80 to 61</u>: Original research having <u>great impact</u> on science, agriculture or general welfare.

These papers are frequently cited in histories of science and in the writings of other scientists doing related research. Authors of these papers will be invited to present their work at scientific symposiums and in scientific review publications and will often be cited for awards for outstanding work.

Note: I estimate that 82 of the 3545 ARS 1964 publications will have <u>great impact</u> on science, agriculture or general welfare.

<u>Rank Orders 60 to 1</u>: Original research having <u>moderate to limited impact</u> on science, agriculture or general welfare.

Papers in the top of this range would be cited frequently in the writings of other scientists. Papers at the bottom of the range would be cited

infrequently. Most research reports of original work will fall in this range--from good to run-of-the-mill.

Note: I estimate that 2464 of the 3545 ARS 1964 research publications will have moderate to limited impact on science, agriculture or general welfare.

Rank Orders 50 to 1: Reviews of research for scientists.

It will be noted that I have an almost complete overlap of rank orders for this group of papers with those next above. This is for the reason that outstanding reviews of science for scientists will have much more impact on science, agriculture or general welfare than many run-of-the-mill reports of original work.

Many papers at national and particularly international meetings are reviews of research rather than presentations of original work. While some monographs present original work, many others are reviews.

Note: I estimate that 507 of the 3545 ARS 1964 research publications are research reviews for scientists.

Rank Orders 40 to 1: Reviews of research for laymen.

Again, I have provided for an overlap of rank orders because certain reviews for laymen have great impact on agriculture and general welfare.

These are reports on research to the users (other than scientists) of research information. At the top of the range would be outstanding Farmers' Bulletins or similar publications, in the middle would be non-technical reviews in trade papers and similar journals, and at the bottom would be popular news articles.

Note: I estimate that 490 of the 3545 ARS 1964 research publications are reviews of research for laymen.

I am adding an appendix as a part of this memorandum which gives examples of papers in the several rank orders. All division directors assisted me in preparing this appendix, but in making one ARS listing it has been necessary in certain cases to modify the rankings suggested by the divisions. Some rankings were raised and others lowered. As a result, I take full responsibility for the rankings shown. Methods papers are hard to rank since most methods are superseded after a period of years. The rule I have followed is to give a fairly high rank to methods that were in widespread use for a period of years after publication. Methods not generally adopted would rank low.

B. PROPORTION OF CREDIT TO EACH AUTHOR

On multiple author papers one should divide the credit in a way that is fair to all. The easiest way is to divide the credit equally. In my opinion, for most papers this would be unfair to the senior author. In those situations where multiple authors take turns in being senior author, dividing the credit equally would be fair. But even if a different

distribution of credit among authors is given, those who take turns in being senior author would end up with equal scores after the number of papers equalled the number of authors. Granting that any distribution of credit will not work in all cases, I suggest the following distribution as a guide. However, in specific cases the senior author may deserve 0.9 of the credit and in other cases only 0.1. Each author should select the proportion of credit that his contribution merits.

one author - 1.0
2 authors - 1st .6, 2nd .4
3 authors - 1st .5, 2nd .3, 3rd .2
4 authors - 1st .45, 2nd .25, 3rd .15, 4th .15
5 authors - 1st .4, 2nd .2, 3rd .15, 4th .15, 5th .1
6 authors - 1st .35, 2nd .2, 3rd .15, 4th .1, 5th .1, 6th .1
7 authors - 1st .3, 2nd .2, 3rd .1, 4th .1, 5th .1, 6th .1, 7th .1
8 authors - 1st .25, 2nd .15, 3rd .1, 4th .1, 5th .1, 6th .1, 7th .1, 8th .1
9 authors - 1st .2, 2nd .1, 3rd .1, 4th .1, 5th .1, 6th .1,7th.1,8th .1,9th .1
More than 9 authors - divide credit equally

C. QUESTIONNAIRE INSTRUCTIONS (ARS FORM T-24)

There are two copies of the questionnaire attached. Both are perforated so that you can tear them out. Complete and return one copy and retain the other copy for your records. The following instructions are given for only those questions that are not self-explanatory.

1. Questions 6 and 7, Division Code and Branch or Laboratory Code. Select the appropriate code numbers from the following list. (For example, those employees in the Cotton Insects Research Branch of the Entomology Research Division would write 33 in question 6 and 33-20 in question 7.)

33		<u>Entomology Research Division</u>
33	01	Office of Director
33	10	Pioneering Research Laboratories
33	15	Apiculture Research Branch
33	20	Cotton Insects Research Branch
33	25	Fruit and Vegetable Insects Research Branch
33	30	Grain and Forage Insects Research Branch
33	35	Insects Affecting Man & Animal Research Branch
33	40	Insect Identification & Parasite Introduction Research Branch
33	45	Pesticide Chemicals Research Branch
33	50	Metabolism and Radiation Research Laboratory
41		<u>Soil & Water Conservation Research Division</u>
41	01	Office of Director
41	10	Pioneering Research Laboratories
41	15	Northeast Branch
41	20	Corn Belt Branch
41	25	Southern Branch
41	30	Northern Plains Branch
41	35	Southern Plains Branch
41	40	Northwest Branch
41	45	Southwest Branch

34		Crops Research Division
34	01	Office of Director
34	10	Pioneering Research Laboratories
34	15	National Arboretum
34	16	Tropical and Subarctic Agricultural Research Programs
34	20	Cereal Crops Research Branch
34	25	Cotton and Cordage Fibers Research Branch
34	30	Forage and Range Research Branch
34	35	Fruit and Nut Crops Research Branch
34	40	Oilseed & Industrial Crops Research Branch
34	45	Tobacco and Sugar Crops Research Branch
34	50	Vegetables and Ornamentals Research Branch
34	55	Crops Protection Research Branch
34	60	New Crops Research Branch
42		Agricultural Engineering Research Division
42	01	Office of Director
42	10	Pioneering Research Laboratories
42	15	Harvesting and Farm Processing Research Branch
42	20	Crop Production Engineering Research Branch
42	25	Livestock Engineering & Farm Structures Research Branch
42	30	Farm Electrification Research Branch
44		Animal Husbandry Research Division
44	01	Office of Director
44	10	Pioneering Research Laboratories
44	14	Chemical Metabolism Laboratory
44	15	Meat Quality Laboratory
44	16	Radiation Biology Laboratory
44	20	Dairy Cattle Research Branch
44	25	Beef Cattle Research Branch
44	30	Swine Research Branch
44	35	Sheep and Fur Animal Research Branch
44	40	Poultry Research Branch
45		Animal Disease and Parasite Research Division
45	01	Office of Director
45	15	Plum Island Animal Disease Laboratory
45	20	National Animal Disease Laboratory
45	25	Beltsville Parasitological Laboratory
45	30	Regional Laboratories and Field Stations
45	35	Foreign Field Locations
51		Market Quality Research Division
51	01	Office of Director
51	10	Pioneering Research Laboratories
51	15	Instrumentation Research Laboratory
51	20	Field Crops and Animal Products Research Branch
51	25	Horticultural Crops Research Branch
51	30	Stored-Product Insects Research Branch
63		Clothing and Housing Research Division
63	01	Office of Director
63	10	Clothing and Textiles Laboratory
63	15	Housing and Equipment Laboratory

71		Northern Utilization Research and Development Division
71	01	Office of Director
71	15	Pioneering Research Laboratories
71	20	Cereal Properties Laboratories
71	25	Cereal Products Laboratory
71	30	Fermentation Laboratory
71	35	Industrial Crops Laboratory
71	40	Oilseeds Crops Laboratory
71	45	Engineering and Development Laboratory
72		Southern Utilization Research and Development Division
72	01	Office of Director
72	15	Pioneering Research Laboratories
72	20	Cotton Chemical Reactions Laboratory
72	25	Cotton Finishes Laboratory
72	30	Cotton Mechanical Laboratory
72	35	Cotton Physical Properties Laboratory
72	40	Food Crops Laboratory
72	45	Naval Stores Laboratory
72	50	Oilseed Crops Laboratory
72	55	Engineering and Development Laboratory
72	60	Fruit and Vegetable Products Laboratory
73		Eastern Utilization Research and Development Division
73	01	Office of Director
73	15	Pioneering Research Laboratories
73	20	Animal Fat Products Laboratory
73	25	Animal Fats Properties Laboratory
73	30	Hides and Leather Laboratory
73	35	Dairy Products Laboratory
73	40	Milk Properties Laboratory
73	45	Meat Laboratory
73	50	Plant Products Laboratory
73	55	Engineering and Development Laboratory
74		Western Utilization Research and Development Division
74	01	Office of Director
74	15	Pioneering Research Laboratories
74	20	Cereals Laboratory
74	25	Wool and Mohair Laboratory
74	30	Fruit Laboratory
74	35	Sub-Tropical Fruit Laboratory
74	40	Vegetable Laboratory
74	45	Field Crops Laboratory
74	50	Poultry Laboratory
74	55	Pharmacology Laboratory
74	60	Engineering and Development Laboratory
52		Transportation and Facilities Research Division
52	01	Office of Director
52	03	Handling and Facilities Research Branch
52	04	Transportation Research Branch
52	05	Wholesaling and Retailing Research Branch

61		Human Nutrition Research Division
61	01	Office of Director
61	15	Food Composition Laboratory
61	20	Food Quality and Use Laboratory
61	25	Experimental Nutrition Laboratory
61	30	Human Metabolism Laboratory
62		Consumer & Food Economics Research Division
62	01	Office of Director
62	05	Survey Statistics Staff
62	10	Food Consumption Branch
62	15	Diet Appraisal Branch
62	20	Family Economics Branch

2. Questions 24 through 33, Publication Summary. For this study a publication is a paper presenting your own work (original research, review, analysis, evaluation, etc., that is reproduced and distributed to 50 or more people. Do not count abstracts. Publications of the same material in two or more places shall be counted only once. However, popular articles are usually based on previously presented technical papers and should be counted. Patents not described in other publications should be treated as publications. Some publications will be a combination of original research and reviews or analyses of other research. In such cases, rank the paper in the range most appropriate to its subject matter content. If you were the author of a Federal or State publication where authorship is not shown, count this paper as one of your own. If you were an author on a regional publication where authors are listed alphabetically, take credit according to your contribution.

Before you answer these questions, I suggest you prepare tables as follows for the periods involved in Questions 24, 25 and 27 or 30 and 31, depending upon which set you answer.

Then from the tables you have prepared, fill in the spaces a through f of Questions 24 through 29 or 30 through 32 in the Publication Summary of the questionnaire.

Period Being Summarized						
Publication Title	Credit		Rank Order		Score
Title	0.3	X	40	=	12
(1)	(2)		(3)		(4)

(1) List your publications during this period.

(2) Refer to section B and using your own judgment, enter the appropriate credit for each paper in the credit column.

(3) Refer to section A and taking account of the rank orders of examples in the appendix, and giving due consideration to future impact of recent papers, give each of your papers its proper rank order.

(4) The credit times the rank order equals the score.

D. PROMOTION HISTORY

Prior to the reorganization of ARS in 1954, scientists were in different Bureaus having somewhat varying personnel policies. Since 1954, except for the two divisions (Market Quality and Transportation and Facilities) which joined ARS in 1964, we have had uniform personnel policies for all scientists. These policies have changed since 1954, but they have changed uniformly for all. As a consequence, the period from January 1, 1955 to January 1, 1965 represents the best period to compare publications (numbers and quality) with promotions to see what, if any, has been the relationship.

This study is designed to help you and those who follow you in ARS. It will be as good as the efforts you put into it. I urge your full cooperation. All information furnished will be treated in confidence and the published analysis will not reveal names. The information is requested for a statistical study and will not be used to evaluate any individual. Please send completed questionnaire to B. T. Shaw, Assistant to Administrator, Agricultural Research Service, Room 512 Cotton Annex, U. S. Department of Agriculture, Washington, D. C. 20250. I would appreciate having the questionnaire returned as soon as possible, but in any event not later than October 1, 1965.

I appreciate your help.

B. T. Shaw

Attachments

ATTACHMENT

Rank Orders 100-81: Original Research

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PUBLICATION AND PROMOTION QUESTIONNAIRE

1. NAME *(Last, first, middle)*

2. BIRTH DATE - MONTH, DAY, YEAR *(Use six digits, i.e. 04-30-29)*

3. SEX MALE ☐ FEMALE ☐	4. YEAR OF ENTRY INTO ARS OR ITS PREDECESSOR AGENCIES	5. ANNUAL SALARY ON 6-30-65 $	SELECT FROM CODE LIST *(Section C, Inst. 1)* 6. DIVISION CODE	7. DIVISION AND BRANCH OR LABORATORY CODE
8. DUTY STATION CODE *(From "Contact Point" on Time and Attendance Report)*	STATE	TOWN	9. ANNUAL SALARY ON 6-30-60 *(Only if employed by ARS on 6-30-60)* $	

10. Did you have full-time employment in research or research and teaching before entering ARS or its predecessor agencies? *(Those employees in the two marketing research divisions who transferred to ARS on July 1, 1964 will answer "Yes" even though some were in a predecessor agency to ARS)*

	Yes
	No

11. If "Yes" in question 10, your previous employer was: *(Check appropriate one; if your previous employment was in two or more, check "d. Other")*

	a. College, University or State experiment station
	b. Industry
	c. Federal Government
	d. Other

12. Ownership or control of facilities in which you work

	a. ARS
	b. Cooperator

13. Are the facilities in which you work

	a. On or near *(10 miles)* a college or university campus
	b. More than 10 miles from a college or university campus

14. What was you highest earned degree on 1-1-65

	a. PhD, ScD, or equivalent degree
	b. MS, MA, DVM, or equivalent degree
	c. BS, BA, or equivalent degree
	d. No degree

15. What was your position title on 1-1-65

	a. Research Scientist *(All Scientists in Pioneering Research Laboratories and all others who work full-time on personal research or in research teams)*
	b. Project leader
	c. Investigations leader
	d. Laboratory director *(Does not report direct to Division Director)*
	e. Field station superintendent
	f. Laboratory Chief *(Reports direct to Division Director)*
	g. Branch Chief *(All scientists in the office of branch chief, i.e. Assist. Chief, Assist. to Chief, etc.)*
	h. Division Director *(All scientists in the office of division director, i.e. Assist. Director, Assist. to Director, etc.)*

16. What was your grade on 1-1-65 *(For those in PL 313 or other non-GS grades use the GS grade equivalent to your salary)* GS-

17. How many years have you been publishing research *(Account for your full career in research without regard to place of employment Begin publication record with the date your first publication was printed but subtract years of service such as military, school or industry where you were unable to publish)*

	a. 31 or more years
	b. 21 to 30 years
	c. 11 to 20 years
	d. 1 to 10 years

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AUGUST 1965

USDA-ARS

18. ARS employment *(Check applicable category and complete the questions specified)*

	a. Employed by ARS continuously since 1-1-55 *(Answer only questions 19 thru 29, and 33)*
	b. Entered ARS after 1-1-55 – including those in Market Quality Division and Transportation and Facilities Division *(Answer only questions 30 thru 33)*

19. What was your grade on 1-1-55 *(For those in PL 313 or other non-GS grades, use the GS grade equivalent to your salary)*	GS-	20. ANNUAL SALARY ON 6-30-56 $

21. Number of grade changes from 1-1-55 to 1-1-65 *(From grades 5 to 7, 7 to 9, or 9 to 11 is a one-grade change; Grades 9 to 14 are 4 changes; Grades 13 to 15 are 2 changes)*

22. Using current definitions of positions, check the one below that best describes your position on 1-1-55

	a. Research scientist *(All scientists in Pioneering Research Laboratories and all others who work full-time on personal research or in research teams)*
	b. Project leader
	c. Investigations leader
	d. Laboratory director *(Does not report direct to Division Director)*
	e. Field station superintendent
	f. Laboratory chief *(Reports direct to Division Director)*
	g. Branch chief *(All scientists in the office of branch chief, i.e. Assist Chief, Assist. to Chief, etc.)*
	h. Division director *(All scientists in office of division director, i.e. Assist. Director, Assist. to Director, etc.)*

23. What was your highest earned degree on 1-1-55

	a. PhD, ScD or equivalent degree
	b. MS, MA, DVM or equivalent degree
	c. BS, BA or equivalent degree
	d. No degree

PUBLICATION SUMMARY

(Read Section C, instruction 2 before completing questions 24 thru 33. After preparing the tables suggested in instruction 2, use those tables to complete questions 24 thru 33)

ITEMS	EMPLOYED BY ARS CONTINUOUSLY SINCE 1-1-55 GIVE YOUR PUBLICATION SUMMARY						ENTERED ARS AFTER 1-1-55 GIVE YOUR PUBLICATION SUMMARY		
(In counting No. years in items b, d & f below, subtract years in military, school or industry where you were unable to publish)	PRIOR TO ENTRY INTO ARS 24	BETWEEN ENTRY AND 1-1-55 25	TO 1-1-55 26	BETWEEN 1-1-55 AND 1-1-65 27	TO 1-1-65 28	BETWEEN ENTRY INTO ARS & 1-1-65 29	PRIOR TO ENTRY INTO ARS 30	BETWEEN ENTRY AND 1-1-65 31	TO 1-1-65 32
a. No. publications *(Total No. papers in the period on which your name appears as author)*	+	=	+	=		(25 + 27)	+	=	
b. Publications per year *(Divide No. publications in item a by the No. years in the period)*			(26a ÷ No. yrs. in 24 and 25)		(28a ÷ No. yrs. in 26 and 27)	(29a ÷ No. yrs. in 25 and 27)			(32a ÷ No. yrs. in 30 and 31)
c. Publication credit for period *(Sum of credits in credit column of table prepared)*	+	=	+	=		(25 + 27)	+	=	
d. Publication credit per year *(Sum of credits in item c divided by No. years in period)*			(26c ÷ No. yrs. in 24 and 25)		(28c ÷ No. yrs. in 26 and 27)	(29c ÷ No. yrs. in 25 and 27)			(32c ÷ No. yrs. in 30 and 31)
e. Publication score for period *(Sum of scores in score column of table prepared)*	+	=	+	=		(25 + 27)	+	=	
f. Publication score per year *(Sum of scores in item e divided by No. years in period)*			(26e ÷ No. yrs. in 24 and 25)		(28e ÷ No. yrs. in 26 and 27)	(29e ÷ No. yrs. in 25 and 27)			(32e ÷ No. yrs. in 30 and 31)

33. What is the highest rank order given to any one publication on which you were sole or senior author

PUBLICATION AND PROMOTION QUESTIONNAIRE

1. NAME *(Last, first, middle)*

2. BIRTH DATE - MONTH, DAY, YEAR *(Use six digits, i.e. 04-30-29)*

3. SEX MALE ☐ FEMALE ☐	4. YEAR OF ENTRY INTO ARS OR ITS PREDECESSOR AGENCIES	5. ANNUAL SALARY ON 6-30-65 $	SELECT FROM CODE LIST *(Section C, Inst. 1)* 6. DIVISION CODE	7. DIVISION AND BRANCH OR LABORATORY CODE

8. DUTY STATION CODE *(From "Contact Point" on Time and Attendance Report)*	STATE	TOWN	9. ANNUAL SALARY ON 6-30-60 *(Only if employed by ARS on 6-30-60)* $

10. Did you have full-time employment in research or research and teaching before entering ARS or its predecessor agencies? *(Those employees in the two marketing research divisions who transferred to ARS on July 1, 1964 will answer "Yes" even though some were in a predecessor agency to ARS)*

	Yes
	No

11. If "Yes" in question 10, your previous employer was: *(Check appropriate one; if your previous employment was in two or more, check "d. Other")*

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	b. Industry
	c. Federal Government
	d. Other

12. Ownership or control of facilities in which you work

	a. ARS
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13. Are the facilities in which you work

	a. On or near *(10 miles)* a college or university campus
	b. More than 10 miles from a college or university campus

14. What was you highest earned degree on 1-1-65

	a. PhD, ScD, or equivalent degree
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	c. BS, BA, or equivalent degree
	d. No degree

15. What was your position title on 1-1-65

	a. Research Scientist *(All Scientists in Pioneering Research Laboratories and all others who work full-time on personal research or in research teams)*
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	g. Branch Chief *(All scientists in the office of branch chief, i.e. Assist. Chief, Assist. to Chief, etc.)*
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16. What was your grade on 1-1-65 *(For those in PL 313 or other non-GS grades use the GS grade equivalent to your salary)* GS-

17. How many years have you been publishing research *(Account for your full career in research without regard to place of employment Begin publication record with the date your first publication was printed but subtract years of service such as military, school or industry where you were unable to publish)*

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ARS FORM T-24
AUGUST 1965

USDA-ARS

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	g. Branch chief *(All scientists in the office of branch chief, i.e. Assist Chief, Assist. to Chief, etc.)*
	h. Division director *(All scientists in office of division director, i.e. Assist. Director, Assist. to Director, etc.)*

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	a. PhD, ScD or equivalent degree
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	c. BS, BA or equivalent degree
	d. No degree

PUBLICATION SUMMARY

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a. No. publications *(Total No. papers in the period on which your name appears as author)*	+	=	+	=		*(25 + 27)*	+	=	
b. Publications per year *(Divide No. publications in item a by the No. years in the period)*			*(26a ÷ No. yrs. in 24 and 25)*		*(28a ÷ No. yrs. in 26 and 27)*	*(29a ÷ No. yrs. in 25 and 27)*			*(32a ÷ No. yrs. in 30 and 31)*
c. Publication credit for period *(Sum of credits in credit column of table prepared)*	+	=	+	=		*(25 + 27)*	+	=	
d. Publication credit per year *(Sum of credits in item c divided by No. years in period)*			*(26c ÷ No. yrs. in 24 and 25)*		*(28c ÷ No. yrs. in 26 and 27)*	*(29c ÷ No. yrs. in 25 and 27)*			*(32c ÷ No. yrs. in 30 and 31)*
e. Publication score for period *(Sum of scores in score column of table prepared)*	+	=	+	=		*(25 + 27)*	+	=	
f. Publication score per year *(Sum of scores in item e divided by No. years in period)*			*(26e ÷ No. yrs. in 24 and 25)*		*(28e ÷ No. yrs. in 26 and 27)*	*(29e ÷ No. yrs. in 25 and 27)*			*(32e ÷ No. yrs. in 30 and 31)*

33. What is the highest rank order given to any one publication on which you were sole or senior author	

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